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CALIFORNIA COOPERATIVE WORK

DEPARTMENT OF THE INTERIOR
UNITED STATES RECLAMATION SERVICE
IN COOPERATION WITH
STATE OF CALIFORNIA

REPORT ON
PIT RIVER BASIN

BY THE RECLAMATION SERVICE OFFICE
AT PORTLAND, OREGON

APRIL, 1915

CALIFORNIA
STATE PRINTING OFFICE
1915

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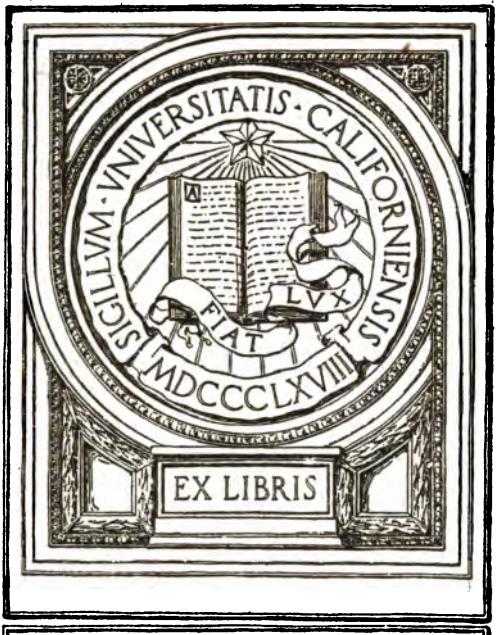

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REPORT ON

PIT RIVER BASIN

BY THE RECLAMATION SERVICE OFFICE
AT PORTLAND, OREGON

E. G. HOPSON, Supervising Engineer
O. W. PETERSON, - - Engineer

APRIL, 1915

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PIT RIVER GORGE BELOW FALL RIVER MILLS.

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INTRODUCTION AND HISTORY.

INTRODUCTION.

This report deals with investigations made in 1914 and 1915 by the United States and the State of California acting in cooperation, through certain engineers of the Reclamation Service duly authorized for the purpose, and the Engineering Department of the State of California, pursuant to the following agreement:

> "*This agreement,* made this 27th day of May, 1914, between the United States of America, by E. G. Hopson, Supervising Engineer, United States Reclamation Service, thereunto duly authorized by and subject to the approval of the Director of the United States Reclamation Service, pursuant to the act of June 17, 1902 (32 Stat. 388), and acts amendatory thereof and supplementary thereto, hereinafter referred to as the Reclamation Law, and the State of California, acting by and through the Advisory Board of the Department of Engineering of said State, witnesseth, that,
>
> *Whereas,* an act of the Legislature of the State of California, Chapter 551, Statutes of 1911, approved April 21, 1911, appropriates the sum of two hundred thousand dollars ($200,000) to be expended by the Department of Engineering for the purpose of rectifying and improving the channels of the Sacramento, San Joaquin and Feather rivers, and such other river channels of the State as the Department of Engineering may determine, and to improve the navigability of said streams, etc.; and
>
> *Whereas,* the Advisory Board of the Department of Engineering, at a regular meeting held February 26, 1914, approved and authorized the expenditure of two thousand five hundred dollars ($2,500) from the appropriation made by Chapter 551, Statutes of 1911 aforesaid, for and in connection with the work herein provided for and described; and
>
> *Whereas,* the Secretary of the Interior, under the provisions of the Reclamation Law, has allotted the sum of two thousand five hundred dollars ($2,500) to be expended on such work in cooperation with the State of California on account of its relation to the irrigation possibilities of the valleys and territory of said State for which the waters hereinafter referred to may constitute an available supply; and
>
> *Whereas,* in accordance with aforesaid act of the Legislature of the State of California, approved April 21, 1911, the terms and provisions of this contract in the text and form herein set out have been exhibited to, and the work proposed to be done hereunder has been approved by, the officers of the Government of the United States, acting under the Department of War thereof, having charge of river work in California, said approval being designated in writing and placed on file with the State Department of Engineering, certified copy thereof being hereto attached and marked Exhibit A;

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Now, therefore, in consideration of the premises and the mutual covenants and agreements herein contained, it is stipulated and agreed between the parties hereto as follows:

1. That investigations and surveys be made in that portion of the State of California included within Pit River drainage area to determine the feasibility of constructing reservoirs and other works necessary or desirable for the full utilization of the waters of the Pit River and its tributaries in improving navigation on the Sacramento River and in other public interests, also to determine the most advantageous utilization of the public land, natural lakes, reservoir sites, waters and other resources of the State and nation within the said drainage area for irrigation or other public uses;

2. That all surveys and investigations contemplated hereunder shall follow a general plan of operation jointly agreed upon by the State Engineer of California and the Reclamation Service through its proper officers;

3. That on completion of the work aforesaid all field notes, original plans, and other data acquired or prepared during said investigations shall be filed with the United States Reclamation Service, but shall be accessible at all times to the State Engineer or his duly authorized representatives upon application, and a copy thereof shall be furnished the State Engineer for official record on request;

4. That on completion of the work herein contemplated a report shall be promptly made and published, outlining the scope of the investigations made, giving detailed statements and estimates of each project investigated, with suitable explanatory plans, maps and other documents as exhibits, together with a summary of expenses incurred in the investigations; that such report shall also contain specific conclusions and recommendations as to the future policy considered most advisable to be followed by the United States and the State of California in utilizing, reserving, or disposing of public lands, waters, reservoir and power sites, and other natural utilities in conformity with the plan of development indicated by this investigation as being to the highest public advantage; that these conclusions and recommendations shall be jointly agreed upon by the State Engineer and the officer of the Reclamation Service having jurisdiction, or in the event of their failure to agree thereon each of them shall submit separate conclusions and recommendations, both of which shall be embodied in the report and published; that such advance reports shall be prepared and furnished to the State Engineer and the Reclamation Service as may be required and agreed upon; that in all reports and publications it shall be clearly shown that the United States and the State of California are joint contributors to the work and the names of cooperating officers shall be stated;

5. That in carrying out all work hereunder one half of the expense shall be borne by the State of California, one half by the Reclamation Service, the total expense to be incurred by each not to exceed two thousand five hundred dollars ($2,500); that each month a detailed statement of costs, together with report of work

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accomplished, shall be made to the Reclamation Service and to the State Engineer of the total expense for the last preceding month, such expense including all proper costs chargeable to the field office and administrative work of the investigation. Such statement shall also give the proportion of expense that has been borne by both the Reclamation Service and the State, and from time to time during the progress of the work such necessary adjustment shall be made in the expenditures on salaries and other expenses by the Reclamation Service and by the State as will equalize the aggregate expenditure by each party, so that at the conclusion of the work the proportion of the expense borne by each shall be equal;

6. That all employees engaged in this investigation paid by the Reclamation Service shall be subject to the established rules and regulations of the United States Civil Service Commission governing such employees; that all employees paid by the State shall be subject to such rules and regulations as the State may provide in such cases; *provided,* that all employees paid by the State shall be subject also to such rules and regulations as the Reclamation Service may establish for the conduct of these investigations, and that in the selection of employees preference will be given to residents of the State, other considerations being equal.

7. No member of or delegate to Congress, or resident commissioner, after his election or appointment, or either after or before he has qualified and during his continuance in office, shall be admitted to any share or part of this contract or agreement, or to any benefit to arise thereupon. Nothing, however, herein contained, shall be construed to extend to any incorporated company, where such contract or agreement is made for the general benefit of such incorporation or company, as provided in section 116 of the act of Congress approved March 4, 1909 (35 Stat. 1109).

In witness whereof, on the day and year first above written, the United States has caused these presents to be signed in its behalf by E. G. Hopson, Supervising Engineer, United States Reclamation Service, and the State of California has caused the same to be executed in its behalf by the Advisory Board of the Department of Engineering through W. F. McClure, State Engineer, thereunto duly authorized by resolution of the said Board, heretofore made.

UNITED STATES OF AMERICA,
By E. G. HOPSON,
Supervising Engineer U. S. Reclamation Service.

STATE OF CALIFORNIA,
By the Advisory Board of the Department of Engineering,
By W. F. MCCLURE, State Engineer.

[SEAL]

Approved: June 11, 1914.
(Signed) F. H. NEWELL,
Director U. S. Reclamation Service.

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WAR DEPARTMENT,
UNITED STATES ENGINEER OFFICE, (Copy)
Room 405 Custom House,
San Francisco, Cal.

DEPARTMENT OF ENGINEERING,
State of California,
Sacramento, Cal.

May 15, 1914.

GENTLEMEN: Referring to the draft of an agreement between the United States Reclamation Service and the State of California transmitted with your letter of May 11, 1914, covering the arrangements for the joint use of Federal and State funds for the purpose of making investigations and surveys on the drainage area of Pit River, California, to determine the feasibility of constructing reservoirs and other works for the full utilization of the waters of Pit River in improving navigation on the Sacramento River and in other public interests, and the preparation of a report upon the result of such investigations, I would state that the work proposed appears to me to be a proper one on which to expend the amount proposed from the appropriation provided in the Act of the Legislature approved April 21, 1911, as affording a useful addition to the engineering information requisite for a study of the means of improving the navigability of the Sacramento River.

Respectfully,
(Signed) S. A. CHENEY,
Major, Corps of Engineers.

"EXHIBIT A."

"*Whereas,* There has been exhibited to this, the Advisory Board to the Department of Engineering, of the State of California, a proposed agreement between the United States of America, by E. G. Hopson, Supervising Engineer, United States Reclamation Service, and the State of California, acting by and thru the Advisory Board, of the Department of Engineering of the State of California, under the terms of which it is proposed to expend the sum of Five Thousand Dollars ($5,000) cooperatively; one half of said sum to be expended from the funds at the disposal of said United States Reclamation Service, and the other half to be expended from the appropriation by the Legislature of the State of California, made by Chapter 551, Statutes 1911, approved April 21st, 1911.

Now, therefore, be it resolved, That W. F. McClure, State Engineer, of the Department of Engineering, of the State of California, be and he is hereby authorized and empowered to execute said above mentioned resolution on behalf of the State of California and of this the Advisory Board of the Department of Engineering, of the State of California.

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OFFICE OF THE DEPARTMENT OF ENGINEERING of the State of California. } ss.

I, Earle Freeman, Secretary of the Department of Engineering of the State of California, hereby certify that the foregoing is a full, true and correct copy of a resolution adopted at a meeting of the Advisory Board of the State Department of Engineering, held May 27, 1914.

Witness my hand and the seal of the Department of Engineering of the State of California this 27th day of May, 1914.

[SEAL] (Signed) EARLE FREEMAN,
Secretary of the Department of Engineering
of the State of California."

In accordance with the provisions of the above agreement an understanding was reached between the two parties as to the scope and character of the operations, and the method of execution, by letters between the State Engineer of California and the Supervising Engineer of the Reclamation Service at Portland, Oregon, during the month of July, 1914. Field and office work has been performed by the Reclamation Service acting through E. G. Hopson, Supervising Engineer, who has personally directed operations. O. W. Peterson, Engineer, has acted as principal assistant in the work. Work commenced on July 25, 1914, and was completed in March, 1915. During the progress of the work the State Department of Engineering has been in general touch with its various features, and on completion of this report it has given careful study to all the matters contained therein and especially to the conclusions and recommendations.

The principal purpose of this investigation is to prepare "specific conclusions and recommendations as to the future policy considered most advisable to be followed by the United States and the State of California in utilizing, reserving, or disposing of public lands, waters, reservoir and power sites," etc., and it is required that "these conclusions and recommendations shall be jointly agreed upon by the State Engineer and the officer of the Reclamation Service having jurisdiction," etc. In conformity therewith these officers have conferred in these and other matters set forth in this report, and are in full agreement, in witness whereof they have affixed their signatures at the end of the chapter dealing with said Conclusions and Recommendations.

PRIOR INVESTIGATIONS.

In 1903–4 the Reclamation Service made a reconnoissance of the entire Pit River basin to determine the amount of storage that might be impounded for the irrigation of lands in Sacramento Valley. Five reservoir sites were located and surveyed, viz., Jess, West, Warm Springs, Round and Big Valleys. A hydrographic

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survey was made of Goose Lake, a possible source of supplementary supply. Preliminary estimates of storage capacity and cost, based on the results of this early investigation, are contained in the report of the California State Water Commission for the year 1912.

In 1909 the Reclamation Service reconsidered the Big Valley Reservoir in connection with a study then being made of Iron Canyon project, and two shafts were sunk at the damsite.

Document No. 81 of the first session of the Sixty-second Congress, published June 29, 1911, considers the feasibility of storage at Big Valley for the controlling of floods in the Sacramento Valley.

In 1912 the Department of Agriculture, in cooperation with the California Conservation Commission, gathered information as to the extent of irrigation development in the Pit River basin, showing the areas irrigated, types of crops grown, etc. These data were published in 1912 report of the Conservation Commission of the State of California.

During 1914 an investigation by the United States Reclamation Service of the Iron Canyon project gave consideration to the use of reservoirs in the Pit River basin and the general subject of water supply from that river. The report dealing with the Iron Canyon project was published by the Reclamation Service in November, 1914, and is frequently referred to in this report.

PRESENT INVESTIGATION.

This investigation, commenced late in July, 1914, was completed in March, 1915. The months of August, September and October, 1914, and a part of February, 1915, were spent in making a field examination. The present areas of agricultural lands, both irrigated and irrigable, were outlined and the nature of present water supplies investigated. All reservoir sites previously considered were inspected and an extended reconnoissance was made to locate additional sites. Studies have been made of possibilities of improving present conditions by fully irrigating such areas as are now inadequately irrigated, and also watering additional irrigable lands now unsupplied.

A new reservoir site of large storage capacity and supply was located in Fall River Valley. Sufficient elevations were obtained to determine approximately the extent to which lands in the valley would be affected by this storage. A survey was made also of the damsite, situated just below the junction of Fall and Pit Rivers.

At Jess Valley a topographic survey was made of a damsite at the immediate outlet.

The principal work performed in this investigation consisted, however, of reviewing, rearranging and classifying the older studies, and bringing them up to date and in harmony with a comprehensive treatment of the resources of the entire basin. In completing this task

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many different authorities have been consulted on such related topics as water power, hydrography, meteorology, geology, agriculture, forestry and transportation. Much valuable information and assistance have been received from local residents, from representatives of the United States Forest Service, the Weather Bureau and the Water Resources Branch of the Geological Survey, and from various public spirited individuals interested in the development of this territory.

GENERAL FEATURES OF THE BASIN.

DEFINITION.

This includes all of the territory hydrographically tributary to the Pit River above its junction with the Sacramento.

BOUNDARIES AND ADJACENT AREAS.

The basin of Pit River, including about 6,000 square miles of northeastern California, lies in Modoc, Lassen, Siskiyou and Shasta Counties. It does not include the Goose Lake Basin, which, although originally a part of this basin, has during recent ages ceased to contribute any appreciable discharge to the Pit, and has practically become a part of the great interior drainage system which does not have an outlet to the sea.

Lassen Peak, the most southerly of the great volcanic peaks in the northwest, is practically at the extreme south limit of the Pit River Basin. From this point the basin extends northwesterly to the Sacramento River, 12 miles north of Redding, and thence almost due north along the ridge directly west of the McCloud to Mt. Shasta. The boundary of the basin extends in the other direction northeasterly to the south terminus of the Warner Range; thence northerly along the crest of this range to a point opposite the south end of Goose Lake. All of the above described boundary of the basin or the divide, as it is properly termed, is extremely well defined, generally by sharp mountain ridges, some of the peaks being among the highest and most celebrated of the continent. The rest of the divide between Shasta and the Warner Range is, however, not well defined topographically; moreover, the extremely porus structure of the region renders any determination of the divide by topographic consideration alone, unsatisfactory.

Surface contours would indicate a divide passing eastwardly from Shasta to the summit of Glass Mountain and thence almost directly east to the southern limit of Goose Lake, as shown on Plate 4. On the other hand, unmistakable indications furnished by the yield of

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the great springs of Fall River point to a drainage basin extending northerly, perhaps as far as Tule and Lower Klamath Lakes or to even include, in the territory northeast of Shasta, the drainage of Butte and Antelope Creeks.

Northeast of the Pit River Basin is the basin of Goose Lake. On the east lie the large alkali lakes that border the Nevada line. On the southeast are numerous local sinks. All of this region on the northeast, east and southeast of the Pit Basin is part of the Great Basin drainage system. On the north lies the drainage system of the Klamath River and Tule Lake. Southeast of Lassen adjacent drainage is toward the Feather River, while along the westerly side drainage is directly into the Sacramento.

TOPOGRAPHIC DIVISIONS.

The basin may be roughly divided into three quite distinct topographic areas. The first is mountainous and lies west of a line between Shasta and Lassen. The second division is adjacent to and east of the first division and west of the Big Valley Range that extends almost directly south from Glass Mountain and follows practically the county lines between Modoc and Lassen Counties on the east and Siskiyou and Shasta Counties on the west. The third division, situate east of Big Valley Range, is mainly a plateau region, including, however, the lofty Warner Range. The general level of the plateau is from 4,000 to 6,000 feet above sea level, averaging about 1,000 feet higher than the average of second division.

From east to west the span across the plateau region between the Warners and the Cascades is nearly 100 miles; from north to south 50 miles. Big Valley and Sheffer mountains rise 2,000 to 3,000 feet above the adjacent plateaus. Big Valley Mountain, although of comparatively small height, marks an important change in conditions both topographic and climatic. To the east the valleys are 1,000 feet or more higher than to the west, and what is of special importance is that the amount of precipitation and the length of the crop growing season is appreciably less on the east than on the west of this mountain range.

Geologically the plateau region east of the Cascades, which includes the second and third topographic divisions, just referred to, is considered by Diller a part of the great continental platform. The Pit (as a part of the Sacramento) has the distinction of being one of the three rivers of the country which rises in this platform and finds outlet to the ocean. "In the United States there are only three rivers, the Columbia, the Klamath and the Sacramento (including the Pit), which cut across the entire mountain belt from the interior platform to the sea." (Diller, U. S. Geol. Survey.)

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MOUNTAIN PEAKS AND LAKES.

The following statements by Prof. Alex. G. McAdie appear in the reports by the United States Weather Bureau: "Shasta, 14,380 feet elevation, is one of the three great peaks on the Pacific Slope, standing like sentinels in a stretch of 700 miles, including the Sierras and Cascades. * * * About two miles west of Shasta is Shastina, elevation 12,433 feet. There are six small glaciers surrounding the peak, known as Whitney, Bolam, Hottum (double), Wintum and Konwatikon. The mountain is snow-covered throughout the year, the snow cover extending down in an ordinary year to the 8,000-foot level during midsummer. There are numerous cinder cones and lava flows, showing the volcanic character of the region.

South of Shasta lies Lassen Peak, elevation 10,437 feet. To the east and north is a large area extending to the Warner Mountains. * * * The most prominent peaks in this range are Bidwell, 8,551 feet; Fandango, 7,848 feet; Cedar, 8,308 feet; Warren, 9,668, and Eagle, 9,934 feet.

In the area between the Cascade Range and Warner Range are numerous lakes, of which the best known are Lower Klamath, Tule, Clear and Goose."

GEOLOGY.

Recent report by the United States Reclamation Service on the Iron Canyon Project states: "The entire territory between Lassen on the south and Tule and Klamath Lakes on the north has even during comparatively recent years been the scene of tremendous volcanic activity. Hundreds of extinct craters and cinder cones are scattered throughout this area, which has been built up by successive flows of erupted matter. The most recent known flow of molten matter is at Lassen and is estimated by geologists to have occurred within 200 years. Even today such phenomena as hot springs, steam vents, not infrequent earthquake shocks, and the recent disturbances at Lassen are indications that the forces that have molded this territory in its present shape are by no means extinct.

"The territory immediately south of Tule and Klamath Lakes has in many respects characteristics that are remarkable, even for this territory. The famous Modoc lava beds, the scene of one of the last Indian fights, lie here. Immense, heaped up masses of shattered lava penetrated by fissures many miles in length and honeycombed by caverns and crevices in every direction are the predominant features. The country is difficult to reach and even more difficult to traverse, owing to its extremely rugged character."

The following quotations are from Diller, showing the relations of the mountains and valleys in and adjacent to the Pit River Basin and

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particularly the geological structure of the Cascades and the plateau region on the east: "The belt of country in northern California and Southern Oregon lying between the Great Basin and the Pacific may be regarded as grouped naturally into two valleys and three mountain ranges. The Coast Range is separated upon the north by the valley of the Willamette, and upon the south from the Sierra Nevada by the broad depression drained by the Sacramento. Near the state line between Oregon and California the three ranges meet in common ground, among a group of ridges and peaks so complex as apparently to render the definition of the ranges a matter of considerable difficulty. It is true, nevertheless, that each range is characterized by its geologic development, and everywhere within this mountain plexus its limits are clearly defined.

"The volcanic ridge of Lassen Peak appears to be a continuation of the Sierras, but in reality * * * it is the connecting link between the Sierras and the Coast Range, and itself belongs geologically to the Cascade Range. * * *

"The Cascade Range is essentially a volcanic range stretching from Lassen Peak in California to Mt. Rainier in Washington, a distance of 450 miles. At both ends the lavas lap up on uplifted mountains of older rocks, the Sierra Nevadas in California and the Cascades in Washington, but between these two from the Columbia River in Washington to the Pit River in California for a distance of nearly 300 miles, the range is composed largely, if not wholly, of igneous rocks that have escaped from a great belt of volcanoes that form the range. The summit of the range is an irregular plateau strewn with many lava and cinder cones, of which each one marks the site of a volcanic orifice tributary to the upbuilding of the range.

"Where best developed, as shown in the Klamath and Columbia River sections, the body of lava forming the range is on an average about 4,000 feet in thickness, but in the greater volcanoes like Hood, Jefferson, Mazama (Crater Lake), Shasta and Lassen it rises to accumulations of 6,000 to 10,000 feet in thickness. The later foundations of the Cascade Range were laid in the Oregon embayment during the cretaceous and early Tertiary times, possibly before the ranges were distinctly outlined. The Tertiary volcanic effusions began in Oregon west of the Cascade Range during the Eocene and possibly a little later in the same epoch eruptions began in the base of the Cascade Range. During the later Tertiary the volcanic activity was greatest, and the bulk of the range, though partly uplifted, was in equal or perhaps in even greater measure upbuilt by flows of viscous andesitic lavas with much ejected material. Basalts are common and some acid lavas are known, but the great bulk of the range is andisitic in strong contrast with the great lava plains east of the Cascades,

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LASSEN IN ERUPTION.

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where the thin basalt flows spread out horizontally like sheets of water. The change from the plains to the mountain slope of the eastern base of the Cascade Range is abrupt and distinct, and due, for the most part, to the fact that the stiff viscous andesite lavas were able to build up steep slopes, while the superheated and highly viscous basalts spread out like water along the irregular mountain front.

"After the close of the Tertiary the volcanic activity waned, although eruptions occurred to within the historic period and possibly even to the present day if the outbursts from the summit of Lassen Peak develop so as to involve molten material.

"However that may be, there is no doubt that the Cinder Cone and its lava field 10 miles northeast of Lassen Peak resulted in one or more eruptions within a century or two. * * * In general, however, the volcanoes of the Cascade Range are considered extinct, and the upbuilding of the Cascade Range completed as far as the actual accumulation of lava is concerned.

"Faulting that has played so large a role in the development of the Sierra Nevada and the Coast Range of California has not given general features to the volcanic mass of the Cascade Range. Small faults are common in the lavas southeast of Lassen Peak, forming lines of bluffs and bringing the ground water to the surface in large springs, a feature which is common in the Klamath Lake Region, and, as pointed out by Russell, along other portions of the range, but these faults have no effect on the general form of the range. * * *

"To the younger flows of basalt the Lassen Peak district is indebted for the development of its most valuable agricultural and grazing lands. At the entrance of every canyon into which the basalt flowed the lava accumulated so as to form a dam for the streams of water. In this way lakes or swamps were produced, and from these, by the gradual accumulation of gravel, sand, mud, infusorial earth, and vegetable matter, the beautiful meadows of ——— and Dixie were produced." * * *

It might be added that Jess, West, Little and a number of other mountain valleys in this basin show evidence of the same development South Fork and Warm Springs Valleys indicate by gravel deposits and topographic features their former existence as lakes, while the outlets of Big and Fall River Valleys show evidence of erosion through old lava flows that once dammed their drainage.

FOREST COVER.

Climatic conditions and especially precipitation are the chief factors in determining the extent and character or type of natural forest cover. A map showing approximately the stands of merchantable timber of different varieties as arbitrarily graded in 5,000 to 10,000, 10,000 to 20,000 and 20,000 and upwards of board feet per acre, has

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been prepared. (See Plate 3.) In preparing this map, information was obtained from officials of four different forest reserve districts and from private individuals. Much of the territory has not as yet been cruised, and it was necessary to some extent to depend upon the personal opinion of various individuals. Probably there are many errors in detail in this map, but such defects are not sufficiently serious to detract from the broad value of the study as indicative of climatic conditions.

The following statement of the distribution of forest cover in this area has been contributed by Mr. T. D. Woodbury, Assistant District Forester of California:

"While soil and light are important requisites, tree growth is dependent to a greater degree upon a fixed minimum average annual precipitation than upon any other single factor. In general, where the annual precipitation is less than 20 inches, tree growth is scanty and composed of dwarfed species which have little commercial value. An annual precipitation of over 20 inches generally results in a commercial forest cover, while the heaviest and most valuable forests in the world,—the redwood forests of the northern California coast region,—are found where the minimum precipitation is greatly in excess of this amount.

"From the above statement the deduction may be made that any factor which affects precipitation or soil moisture brings about a corresponding change in the density and composition of the forest cover. For example, northerly and easterly slopes are less exposed to the sun's rays than southerly or westerly, therefore, the soil and air moisture content is greater in such situations, and in protected gulches and canyons. For this reason we find on these slopes the heaviest stands of the most valuable species.

"While trees, like other forms of vegetation, prefer a rich sandy loam soil, on the whole the character of the soil has far less bearing upon the determination of and character and amount of forest cover than precipitation. Fairly well drained soils of so rocky a character as to be absolutely without value for agriculture will produce a heavy timber crop where the rainfall is ample. Again, like other forms of vegetation, trees require a certain amount of light. Since, however, light is universally distributed, this factor has but little bearing on the determination of local forest conditions.

"So intimate is the relation between precipitation and tree growth, however, that with information at hand regarding the precipitation in a given region, the character of the forest may be determined with a fair degree of accuracy. Conversely the amount and character of forest cover serves as an indication of the amount of precipitation where other records are lacking.

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"Bearing in mind the above statement of general principles and referring to the timber map of the Pit River drainage basin on Plate 3, we should expect to find the heaviest and choicest stands indicative of the areas of heaviest precipitation. The heavily timbered strip between Mt. Shasta and Mt. Lassen, denoted in the larger green dots on the map, is located along the divide between the Sacramento and Pit River drainage areas. This strip intercepts storms from the Pacific Ocean and the precipitation there varies from about 40 inches on the western border to 24 inches on the eastern. The great bulk of this belt below 6,000 feet elevation is made up of forests composed of sugar and yellow pine (*Pinus lambertiana* and *Pinus ponderosa*) with white fir (*Abies concolor*) and incense cedar (*Libocedrus decurrens*) in mixture.

"These species make up the most valuable commercial type in the California Sierras and the one in which the large pine lumbering operations of this State are being carried on. Within this type sugar pine and white fir are particularly dependent on moisture and therefore occur on the northerly and easterly slopes or in the most favored and protected situations, as would be expected, leaving the less desirable localities in the possession of the yellow pine and scattered cedar. In certain fairly favorable situations all of these species occur together in a mixed stand, the composition of which varies considerably with changes in slope, exposure and moisture conditions. The presence of any considerable percentage of sugar pine in the mixture, however, is always indicative of favorable moisture conditions.

"Within the belt between 6,000 and 8,000 feet where the effect of altitude and exposure counteract somewhat the abundant moisture, the timber type consists of lodgepole pine (*Pinus contorta*) and California red fir (*Abies magnigica*). On this account the forest at the highest elevations is not as dense or as valuable as that at moderate altitudes.

"Within the great comparatively level belt of country which extends eastward from this area of heavy timber to the Warner Mountains on the eastern border of this drainage basin, precipitation decreases from west to east. In the western portion of the area the annual precipitation averages about 20 to 24 inches, while in the eastern and southeastern portion it amounts to only 14 inches. This decrease in the annual supply of moisture is directly reflected in the character and composition of the forest cover. On large areas of the poorer rocky soils situated between 4,200 and 5,000 feet elevation within this intermediate area the juniper type has taken possession because of its ability to withstand drought. Where precipitation increases slightly on account of some local change in conditions or where more soil moisture is available, as on northerly and easterly slopes or on protected gulches, light stands of pure yellow pine are found. In still more moist situations cedar and fir occur in mixture with yellow pine, and in a few favored localities,

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such as Big Valley Mountain and Happy Camp Mountain, where exposure and soil conditions are most favorable, the forest is made up of a mixed type containing sugar pine as well as yellow pine, white fir and cedar.

"When the Warner Mountains are reached precipitation again increases with elevation and we find the same forest law governing the composition and density of the stand. In ascending this range a belt of juniper is first encountered, then pure yellow pine on the south and west slopes. Still higher up between 5,500 and 7,500 feet elevation the heaviest stands occur. These contain varying proportions of white fir and incense cedar, in addition to the yellow pine, and are found at their best on north and east slopes. Between 7,500 and 9,000 feet elevation the effect of exposure and altitude is again felt and the forest reverts to a mixture of rather unimportant abnormally formed trees, or the mountains are so rocky that there is no tree growth.

"This brief description of timber conditions within this drainage basin is intended simply to elucidate the map and to make clear the relative watershed value of the various portions of the drainage area as indicated by the character of the cover."

PRECIPITATION.

The following tabulations give all available and pertinent data from the records of the United States Weather Bureau within the basin:

Monthly Precipitation, in Inches, at Alturas, Modoc County, California. Elevation 4,400 feet.

	1903-04	1904-05	1905-06	1906-07	1907-08	1908-09
October	----------	1.00	.22	.27	1.90	1.42
November	----------	.55	.94	.97	1.11	.66
December	----------	1.86	.52	3.52	1.82	.67
January	----------	.98	3.87	1.35	1.04	4.47
February	----------	1.31	1.08	2.87	.16	1.58
March	3.10	2.96	3.20	4.13	.26	.53
April	2.13	.51	.66	.39	.35	.66
May	.94	1.41	2.46	1.21	1.31	.73
June	.22	.78	.96	1.68	.42	.49
July	.55	.0	.01	.55	.21	.10
August	.11	.0	.05	.27	.19	.26
September	.57	.27	.60	1.09	.10	.67
Totals	----------	11.63	14.57	18.30	8.87	12.24

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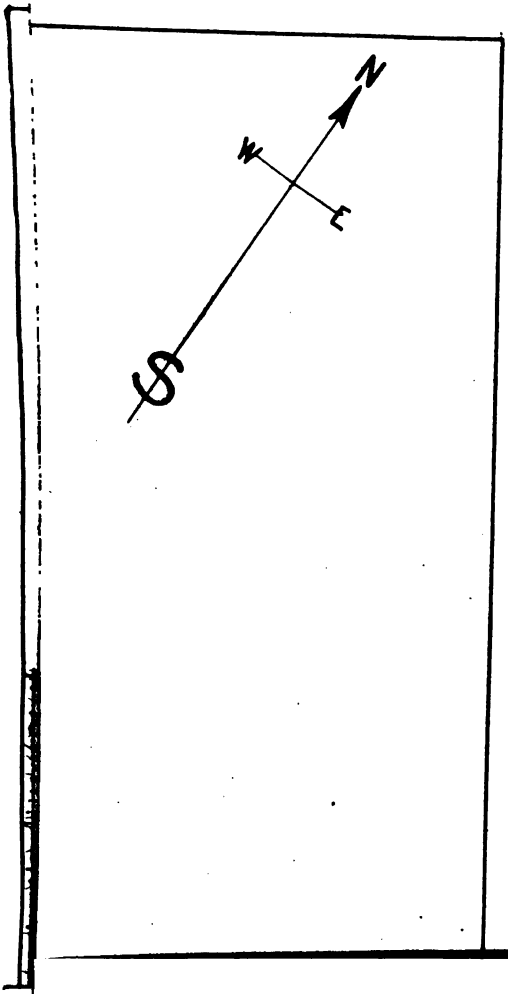

—Continued.

	1914-15
.0	1.51
59	.44
52	.40
28	1.30
18	----------
11	----------
51	----------
34	----------
34	----------

34	----------
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	1914-15
	3.27
29	1.94
37	2.88
93	5.79
98	----------
27	----------
41	----------
94	----------
28	----------
09	----------

20	----------
76	----------

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	1914-15
02	5.29
60	1.71
46	7.55
59	10.36
75	----------
53	----------
59	----------
24	----------
82	----------
06	----------

17	----------
85	----------

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August	
September	
Totals	

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Monthly Precipitation, in Inches, at Alturas, Modoc County, California—Continued.
Elevation 4,400 feet.

	1909-10	1910-11	1911-12	1912-13	1913-14	1914-15
October	1.40	1.01	.37	.24	.10	1.51
November	1.94	2.59	.62	.59	1.59	.44
December	1.78	2.25	.59	.58	2.52	.40
January	1.27	3.16	.99	1.92	2.28	1.30
February	1.28	.59	.38	.16	.48	----------
March	.43	.68	1.53	1.43	.31	----------
April	.26	.97	2.71	2.08	1.51	----------
May	.63	.59	1.07	.68	1.64	----------
June	.24	1.01	.90	2.20	.64	----------
July	2.29	.97	.64	3.00	----------	----------
August	0	0	.53	.87	.04	----------
September	1.91	.58	.87	.22	.07	----------
Totals	13.43	14.40	11.20	13.97	11.18	----------

Mean 13 inches.

Monthly Precipitation, in Inches, at Burney, Shasta County, California.
Elevation 3,300 feet.

	1909-10	1910-11	1911-12	1912-13	1913-14	1914-15
October	*	0	1.38	.97	0	3.27
November	*	4.58	.80	2.78	4.29	1.94
December	*	3.34	1.97	2.47	9.37	2.88
January	*	11.92	6.38	4.95	14.93	5.79
February	*	3.22	.57	.70	3.98	----------
March	1.65	3.60	2.77	2.53	1.27	----------
April	.34	3.06	2.86	1.73	3.41	----------
May	0	1.46	3.04	1.78	.94	----------
June	0	.80	1.64	2.78	2.28	----------
July	0	0	0	.75	.09	----------
August	0	0	0	.56	0	----------
September	0	.19	3.56	0	.20	----------
Totals	----------	32.17	24.97	22.00	40.76	----------

Mean 30 inches.
*No record.

Monthly Precipitation, in Inches, at McCloud, Siskiyou County, California.
Elevation 3,410 feet.

	1911-12	1912-13	1913-14	1914-15
October	1.51	2.34	.02	5.29
November	8.24	8.62	9.60	1.71
December	2.46	2.85	12.46	7.55
January	8.96	10.80	23.59	10.36
February	2.55	.92	9.75	----------
March	6.07	1.42	3.53	----------
April	6.10	2.94	4.59	----------
May	4.96	3.05	3.24	----------
June	1.46	2.77	1.82	----------
July	1.03	.97	.08	----------
August	1.02	.70	0	----------
September	4.76	.07	1.17	----------
Totals	49.12	37.45	69.85	----------

Mean 52 inches.

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Monthly Precipitation, in Inches, at Montgomery Creek, Shasta County, California.
Elevation 2,200 feet.

	1909-10	1910-11	1911-12	1912-13	1913-14	1914-15
October	----------	1.02	----------	2.93	.10	7.87
November	----------	8.57	----------	9.46	10.97	3.75
December	----------	----------	----------	6.55	9.68	2.20
January	9.19	----------	15.69	3.60	21.00	10.83
February	9.85	----------	4.40	.10	8.55	----------
March	5.39	----------	6.90	6.30	2.68	----------
April	1.63	----------	5.77	3.39	8.64	----------
May	----------	----------	4.51	3.76	1.55	----------
June	.35	----------	2.13	2.77	4.98	----------
July	----------	----------	1.30	.64	0	----------
August	----------	----------	0	.30	0	----------
September	1.22	----------	5.48	0	.32	----------
Totals	----------	----------	----------	39.80	68.47	----------

Mean probably about 45 inches.

Monthly Precipitation, in Inches, at Steel Swamp, Modoc County, California.
Ten miles east of Clear Lake. Maintained by U. S. Reclamation Service.

	1904	1905	1906	1907	1908	1909
January	----------	1.25	4.00	.90	.38	3.39
February	----------	1.12	2.07	3.80	.36	2.05
March	----------	1.70	3.62	4.88	1.24	1.25
April	----------	.20	.09	.70	*	0
May	----------	2.62	2.70	2.25	*	1.20
June	----------	.30	1.05	2.11	*	.50
July	----------	0	.60	.20	.15	.02
August	0	0	0	1.71	.42	.01
September	.92	.42	.76	.72	0	.05
October	1.01	.40	.41	2.13	2.00	.43
November	.42	1.25	2.05	1.06	*	3.09
December	3.11	.23	3.70	1.98	1.00	.52
Totals	----------	9.49	21.05	22.44	----------	12.51

Mean 16 inches.
*No record.

Monthly Precipitation, in Inches, at Clear Lake, Modoc County, California.
North end of Clear Lake. Maintained by U. S. Reclamation Service.

	1910	1911	1912	1913	1914
January	.85	2.97	1.21	2.35	2.27
February	.43	1.26	2.23	.24	.67
March	.50	.77	1.64	.59	.47
April	.16	1.05	2.82	2.02	1.55
May	.78	1.01	1.93	1.22	*
June	.34	.75	2.05	2.39	
July	.11	.27	.48	1.99	
August	0	0	.43	.08	
September	.33	.46	.96	.32	
October	.81	.51	.20	.93	
November	2.67	.81	1.18	.93	
December	2.52	.60	1.23	3.13	
Totals	9.50	10.46	16.16	16.19	

Mean 13 inches.
*Abandoned May 1, 1914.

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To enable a thorough understanding of general conditions of precipitation in the basin to be had, with the greatest facility, a special map, Plate 4, has been prepared. The local intensity of precipitation is brought out by the depth of hatching on the map. The isohyetose lines also give in greater detail the distribution of snow and rainfall. All of this work has been based primarily on such records as exist of average annual precipitation at points within and in the vicinity of the basin. The map has been supplemented by a smaller scale map, Plate 5, which shows in relief the entire topography of Northern California and the relation of precipitation in the basin with that in the larger territory. A careful examination and comparison of these two sheets is essential for a full grasp of conditions.

In preparing Plate 4 the basis of the sheet was the United States Weather Bureau stations indicated by circle. This data was supplemented by consideration of the forest cover previously discussed and shown on Plate 3. Important additional data was obtained by personal narrative and descriptions of men intimately acquainted with the country, such as county surveyors, forestry men, cattle men and others.

In preparing Plate 5 the records of the United States Weather Bureau have of course been the basis. To a certain extent older maps showing precipitation in this region have been used, and all available data prepared by engineers for public and private interests have been utilized. The influence of topography and exposure, as summarized herein in the section entitled "Relation between Topographic Features and Precipitation in Northern California" in an article written by G. H. Willson, District Forecaster for the Weather Bureau in California, and also the influence of the high range extending from Lassen Peak to Mt. Shasta, as indicated by an average annual precipitation of about 52 inches at McCloud and 45 inches at Montgomery Creek, were given special consideration in preparing Plate 5. This study has resulted in assuming heavier precipitation on the Warner Range than had previously been estimated, due to unmistakable evidence such as snowfall, run-off and forest cover, which indicate a maximum of fully 30 inches near the higher elevations. It will also be observed that the precipitation on the north coast of California is excessively heavy, and that it rapidly decreases from west to east, except as locally influenced by mountain ranges.

RELATION BETWEEN TOPOGRAPHIC FEATURES AND PRECIPITATION IN NORTHERN CALIFORNIA.

In order to better illustrate the variation in precipitation from west to east and show how relatively small is the amount east of the Cascades, a cross section of Northern California from Humboldt Light House on the ocean to Cedarville east of the Warners, is given,

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Plate 6, on which also the average annual precipitation at various points is shown. This section passes through Eureka, Weaverville, Shasta, Redding, Montgomery Creek, Burney and Alturas, and likewise crosses most of the important valleys and all the mountain ranges at about their average elevation.

Mr. G. H. Willson, of the United States Weather Bureau, in discussing the influence of elevation on rainfall in California, makes the following statements: "Generally speaking, precipitation increases rapidly with elevation, but the differences found in the amounts of precipitation measured at places in the same vicinity, and at the same elevation, plainly indicate that there are other important factors besides elevation to be considered.

"The rainfall chart of Northern California gives a good general idea of the distribution of precipitation and shows a close relationship between it and the topography of the State; also that the greatest amounts are found in the foothill and mountain districts.

"In this study of the relation of rainfall to elevation in Northern California a study of diagrams (not published) for places having the same latitude quite clearly illustrates the following general facts:

1st. "The rainfall on the immediate coast is less than it is a short distance inland.

2d. "The western slopes of the mountains have more rain than the eastern at the same elevation.

3d. "At the eastern base of the mountain ranges the rainfall is less than it is further east in the valleys. (This condition is not pertinent to the Pit River basin.)

4th. "On the western slopes of the mountain ranges the rainfall is greatest where the mountains are steepest. The greatest precipitation is not on the summit of the Sierras, but somewhat lower, on the slope facing the rain bearing winds (generally western).

"From the above it will be noted that those places most exposed to the rain bearing (south to west) winds of the Pacific, other factors being equal, receive the greatest rainfall, that the winds do not give up their moisture readily in passing over the ocean and immediate coast where the land is low, but retain it until forced upward over the hills and mountains. Those slopes of the hills and mountains upon which the rain-bearing winds impinge and are forced over receive the greatest precipitation. Any rapid upward deflection of the atmosphere cools and greatly lessens its capacity for holding moisture. Consequently where rain-bearing winds are forced over the steep mountains they deposit most of their vapor in ascending, and descend on the leeward side of the range comparatively dry."

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The effectiveness of mountain masses in causing increased precipitation on their windward or westerly slopes and in reducing the amount on their leeward or easterly slopes is well illustrated on Plate 6. At sea level on the Humboldt Coast the precipitation is 38 inches, on the higher westerly slopes of the Coast Range it exceeds 60 inches. At Redding it is about 38 inches, while at Montgomery Creek, some 1,600 to 1,700 feet higher, the amount is 45 inches. On passing over the Cascades from Montgomery Creek to Burney, the precipitation reduces from 45 to 30 inches, notwithstanding the 1,100 feet greater elevation at Burney than at Montgomery Creek.

In connection with the Pit River Basin one of the most striking changes in precipitation conditions occurs in passing from west to east of Big Valley Mountain. At the west, in Fall River Valley, the annual precipitation is apparently about 20 to 24 inches; at the east of the range in Big Valley it is about 13 inches, as indicated by a short record at Lookout and the Alturas records. In contrast with this decrease in rainfall the territory east of Big Valley Mountain averages about 1,000 feet higher in elevation than that to the west. Sheffer Mountain, between Big Valley and Alturas, does not exert a pronounced influence on precipitation. The storms appear to rise over the long sloping spurs that extend to the west with little effect on the areas to the east, and with only a moderate increase in precipitation on the westerly slopes of this mountain.

The average of a ten-year record at Alturas is 13 inches. On the higher slopes of the Warners the annual depth undoubtedly amounts to a minimum of 24 to over 30 inches. The large increase over the Warners is probably due to the very abrupt face which these mountains expose to eastward moving storms as well as their elevation. Cedarville, at the easterly base of this range, has an average of about 14 inches, the increase of an inch over Alturas being due, no doubt, to the proximity of this place to the crest of the mountains and the local influence of a comparatively low open gap in the mountain range due east of this town. That such depth of rainfall does not extend far from the Warner range easterly into Nevada is quite evident from the barren desert conditions that prevail within ten to twenty miles of the crest of the Warners. It is probable that the average precipitation is considerably less than 10 inches over the areas to the east of this mountain range.

ZONE OF HEAVY PRECIPITATION EASTERLY FROM MOUNT SHASTA.

There appears to be a quite pronounced zone of relatively heavy precipitation extending from the south side of Shasta on the west through the gap between Big Valley Mountain and Glass Mountain and finally

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passing to the north and east of Goose Lake. This zone is generally marked by the heavy forest growth and greater depth of snow. Its cause is probably due to the deflection of air currents by topography.

ARIDITY, THE PREDOMINATING FEATURE EAST OF THE CASCADES.

The predominating feature of precipitation conditions over the greater part of the Pit River Basin east of the Cascades, and particularly over the valley or agricultural areas, is its small amount. West of Big Valley Mountain, in Fall River, Hat Creek and Burney Valleys, the amount is 20 to 24 inches with probably 24 to 30 inches near the head of Hat Creek Valley. East of Big Valley Mountain, in Big Valley, Warm Springs Valley and in North and South Fork Valleys the average does not exceed 13 to 14 inches. As most of this precipitation occurs during the winter months, principally as snow, the entire region is relatively arid, with conditions of aridity particularly pronounced east of Big Valley Mountain.

CLIMATIC FEATURES.

Contributed by G. H. Willson, District Forecaster, San Francisco. "Climatically, the northeastern portion of California, especially the Pit River drainage area, is entirely different from the portion of the State west of the mountains (Cascades). The chief characteristics are a scarcity of rainfall, an abundance of sunshine, wide range of temperature and rapid evaporation. The topography is varied and marked differences in both temperature and rainfall prevail at places but a few miles apart. A marked feature during the late spring, summer and early fall is the warm days and cool nights; and although afternoon temperatures often exceed 100 degrees, they cause no great inconvenience. During cold periods in the winter the minimum temperature often falls below zero.

The precipitation is generally confined to the winter months, although thunder showers are not infrequent in the late summer, but they can not be depended upon for crop growth."

TEMPERATURES.

The following tables of records at Alturas and Burney give mean, maximum, and minimum monthly temperatures at these points and record of killing frosts at Alturas.

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Monthly Temperatures, in Degrees Fahrenheit, at Alturas, Modoc County, California.
Elevation 4,400 feet.

	1906			1907			1908		
	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.
January	26.5	54	— 7	25.5	47	— 8	34.7	58	10
February	37.2	56	19	42.8	66	21	35.8	69	11
March	35.8	68	—28	35.6	62	4	37.4	71	7
April	47.0	80	20	48.6	73	24	47.4	82	13
May	50.0	83	25	52.6	86	23	47.2	78	21
June	56.6	87	32	55.8	87	31	56.1	92	25
July	70.7	98	40	64.8	95	34	69.9	104	35
August	67.2	97	36	62.3	94	31	65.2	105	24
September	57.6	90	27	56.6	96	27	58.0	94	15
October	48.4	85	14	54.0	85	26	45.9	82	15
November	36.3	72	5	38.6	68	14	40.3	76	12
December	33.6	56	4	35.4	60	8	27.3	57	—23
Annual	47.5	98	—28	47.7	96	— 8	47.1	105	—23

Monthly Temperatures, in Degrees Fahrenheit, at Alturas, Modoc County, California—Continued.

	1909			1910			1911		
	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.
January	31.8	53	—21	22	51	—30	26.7	54	—21
February	34.1	52	6	29	57	—13	23	47	—16
March	38.2	64	16	44.9	72	19	40.4	79	16
April	44.3	75	15	48.8	87	18	43.8	78	13
May	49.6	88	18	55.4	98	25	48.3	82	19
June	60.1	91	31	59.8	97	27	60	92	29
July	62.8	95	29	69.2	100	33	68	101	34
August	64.6	100	30	63	96	25	63	96	30
September	57.5	91	23	55.8	87	20	51.8	87	17
October	49.2	84	19	49.4	84	22	46.9	79	18
November	40.0	69	9	59.2	75	— 1	37.4	68	4
December	28.3	51	— 3	35.1	61	13	25.8	63	— 8
Annual	47.6	100	—21	49.3	100	—30	44.6	101	—21

Monthly Temperatures, in Degrees Fahrenheit, at Alturas, Modoc County, California—Continued.

	1912			1913			1914		
	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.
January	32	61	—26	21.6	51	—21	34.1	58	33
February	36.6	64	5	22.4	52	—14	36.4	59	9
March	35.4	66	— 4	35.4	65	5	44.2	78	19
April	40.9	72	17	45.4	76	18	48.0	82	21
May	51.1	82	28	54.0	87	26	56.4	92	29
June	59.2	93	29	58.5	86	29	59.9	98	26
July	64.8	99	32	65.8	94	34	68.3	98	37
August	63.4	96	28	67.4	97	37	67.7	102	34
September	55.6	90	25	59.9	95	23	56.6	91	24
October	44.0	76	15	48.6	85	13	49.4	86	20
November	41.1	65	14	40.0	73	10	40.2	72	6
December	30.4	55	4	30.8	58	1	25.2	49	— 9
Annual	46.2	99	—26	45.8	97	—21	48.9	102	— 9

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Monthly Temperatures, in Degrees Fahrenheit, at Burney, Shasta County, California.
Elevation 3,300 feet.

	1911			1912		
	Mean	Max.	Min.	Mean	Max.	Min.
January	32.2	60	— 2	34.2	58	—15
February	29.8	52	— 2	40.4	65	13
March	43.3	83	18	39.0	70	16
April	46.4	81	14	43.4	75	22
May	50.0	80	25	52.4	83	26
June	59.7	86	34	58.2	98	31
July	66.8	98	35	61.6	95	31
August	61.4	90	32	62	91	28
September	52.7	84	24	56	88	30
October	47.8	77	24	35.4	78	18
November	39.1	71	12	41.4	64	18
December	29.6	59	— 7	33.1	55	10
Annual	46.6	98	— 7	46.4	98	—15

Monthly Temperatures, in Degrees Fahrenheit, at Burney, Shasta County, California—Continued

	1913			1914		
	Mean	Max.	Min.	Mean	Max.	Min.
January	29.1	57	3	32.6	53	9
February	33.2	63	5	34.8	59	7
March	38.3	71	13	44.4	77	21
April	46	80	21	46.4	79	24
May	54.6	84	23	54.3	87	31
June	57.8	83	32	57.2	90	26
July	63.4	89	34	64.6	94	37
August	66.0	97	33	64.1	96	35
September	58.5	95	27	54.0	83	26
October	49.3	84	17	48.1	77	24
November	39.9	67	16	37.6	69	13
December	31.2	57	9	27.6	55	— 2
Annual	47.3	97	3	47.1	96	— 2

Frosts. Killing frosts at Alturas. The following notes are taken from the annual weather reports of California:

	Last in spring	First in autumn
1905	May 21	August 28
1906	May 16	September 11
1907	June 16	August 10
1908	June 22	August 26
1909	May 24	August 24
1910	June 8	August 29
1911	Every month of the year in the mountains.	
1912	Every month of the year in the mountains.	
1913	Every month of the year in the mountains.	
1914	Nearly every month of the year in the high mountains.	

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From this record it appears that killing frosts are liable to occur every month in the year, although less prevalent from the middle of June to the middle of August.

These frost conditions must not, however, be considered as abnormal. In practically all the higher plateau and mountain regions such conditions prevail. Elevated valleys like the Klamath, the Deschutes, the Carson and other well known agricultural regions in the Pacific States suffer to a greater or less extent from summer frosts. Agricultural losses by these summer frosts are confined almost wholly to the tenderer vegetables and fruits. Staple crops like fodders and grains are rarely affected. In the more sheltered and best located areas of these elevated plateau lands the effect of frost is hardly appreciable and plants of great variety and delicacy can be successfully raised.

RUN-OFF.

GENERAL.

Of the precipitation which falls on any area a part is lost by direct evaporation into the atmosphere. The remainder may flow off in surface streams, or sink into the ground, or both. Evaporation is most pronounced from all water surfaces and from wet and swampy lands. Surface streams may later be converted into underground supplies and conversely underground supplies may later issue to the surface as springs.

CLASSIFICATION OF CATCHMENT AREA.

General. The basin is structurally volcanic as described in the section on Geology. Different localities, however, differ very markedly in structural conditions affecting run-off. A map of the basin showing localities where widely differing conditions of run-off prevail is given on Plate 7.

A large portion of the basin includes elevated mountain masses, to a certain extent porous and capable of considerable underground storage, from which issue numerous perennial springs. The mountain slopes are, however, mostly steep and rapidly shed such surface waters as are not at once absorbed by the substrata. This portion of the basin is undoubtedly by far the most fruitful in yield, due mainly to the heavy precipitation, the result of elevation and exposure already referred to, and to the relatively small evaporation and absorption losses. Portions of the basin of this type are shown on Plate 7 by cross hatched lines, and are for convenience referred to as the "mountain areas."

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The portion of the basin next to be considered is the shattered an porous lava zone or belt extending between Shasta and Tule lakes o the north down to and including the Lassen territory on the soutl This area is almost unique in the fact that, in spite of the comparativel heavy precipitation it receives, its surface sheds practically nothin into the water courses or channels, all run-off being confined to spring many of which may justly be termed underground rivers. This par of the basin is shown on Plate 7 by plain hatched lines, and is referre to hereafter as the "porous lava areas."

The remainder of the basin is shown on Plate 7 by dashes, and con sists mainly of rolling plateaus and benches capped almost entirely wit adobe soil from 2 to 5 feet in thickness. Much of this is heavily tim bered but mainly it has sage and scattering juniper growth. The sur face soil is also to a large extent covered with angular basaltic fragments or float rock, as it is locally termed. This adobe soil is markedly re tentive of moisture when the latter is not in excessive quantity. Pre cipitation, as already stated, is scanty and usually occurs in a manner that permits its gradual absorption and retention in the surface soil where it is held until evaporated. The result is that practically no surface run-off occurs from areas of this class, save during or after storms of exceptional severity or duration when the absorptive capacity of the soil is overtaxed, nor is there any appreciable accretion to the underground supply as evidenced by the almost total lack of springs in this territory. In short, these areas are the least fruitful in run-off of any in the basin. For convenience these areas are referred to as the "plateau areas."

Mountain Areas. The streams draining the mountain areas referred to above derive a very large proportion of their supply from substantial perennial springs issuing from the lower mountain slopes. In spring time, however, the proportion of surface accretions is heavy and floods of magnitude frequently occur, but the period of surface discharge is short. The discharge of the streams, however, generally indicates a fairly heavy absorption and storage by the substrata. The ratio of total run-off of these streams in very dry years to that of very wet years is probably in no instance greater than 1 to 2.5. On South Fork of Pit River at Jess Valley the ratio for 1903–04, an excessively wet year, to 1904–05, a comparatively dry year, was about 1 to 15. On Ash Creek at Adin the ratio for the same years probably was 1 to 2. On the McCloud the maximum variation to date is 2,400,000 acre feet in 1903–4 to 1,260,000 acre feet in 1911–12, or slightly less than 1 to 2. The large flood run-off on this river is caused at times by warm rains in winter and spring that extend up to elevations of 4,000 feet or more.

While these streams are not regulated by underground storage to the extent of Fall River and Hat Creek, their supply is dependable. The

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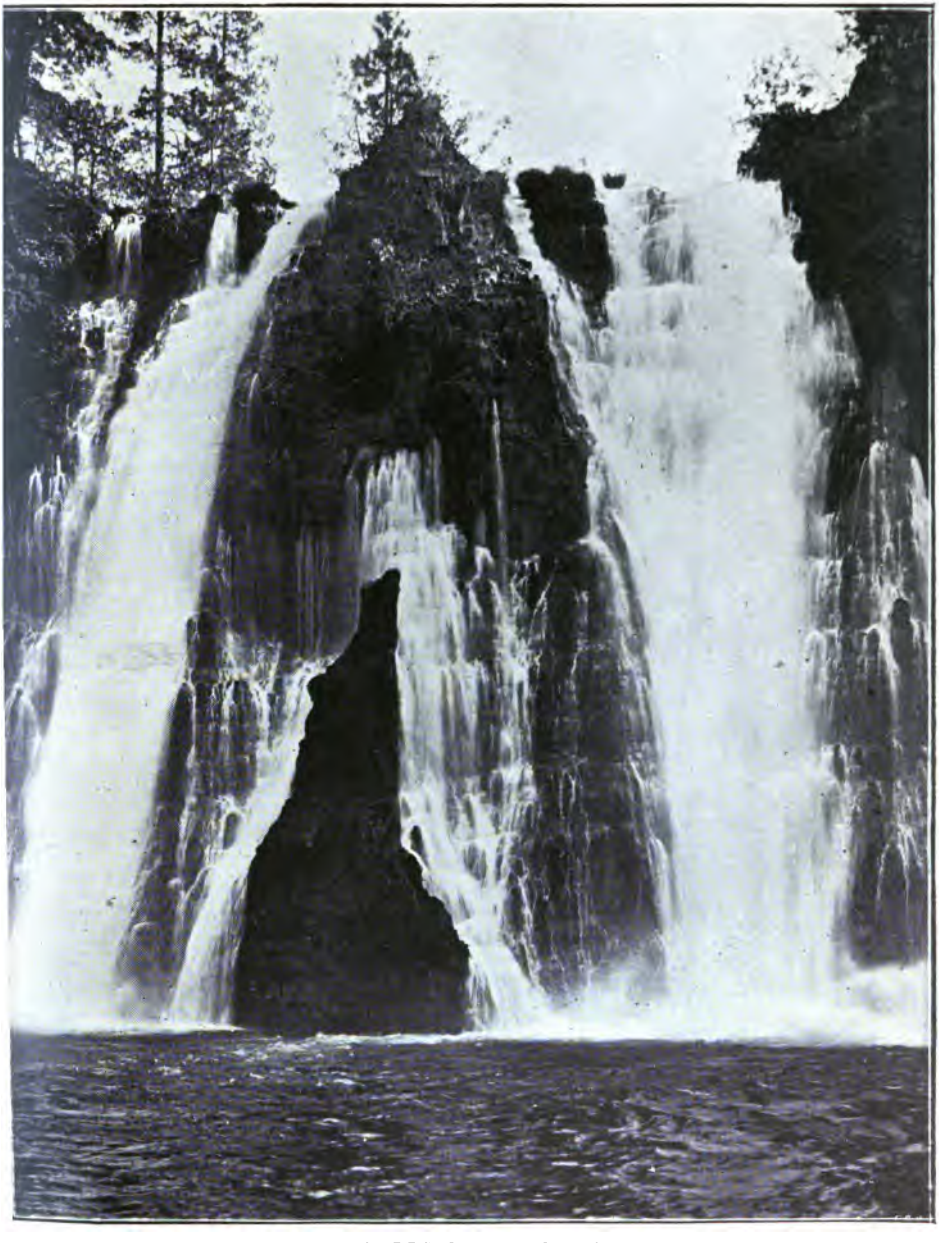

BURNEY FALLS ON BURNEY CREEK.

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chief streams of this type are the creeks which feed South Fork from West and Jess valleys, Ash Creek, Willow Creek, Horse Creek, Beaver Creek—all east of Fall River and Hat Creek—practically all the small creeks which enter the Pit below Burney Creek and McCloud River. Burney Creek might also be included in this classification, as its flow is regulated only below Burney Valley, into which the drainage from the mountains at the south ordinarily sinks, issuing later from large springs at Burney Falls.

As the precipitation on the mountain area, so-called, east of the Cascades varies from 18 to 30 inches and from 30 to 60 inches in the Cascades, the stream flows are not only well sustained but also of relatively large amount.

Porous Lava Areas. Fall River and Hat Creek are the most conspicuous examples of streams fed entirely by spring flow. The report on Iron Canyon project in reference to streams in this area states: "The aggregate contributions from springs entering Pit River, from all sources above its junction with McCloud River, is about 2,500 second feet, possibly a unique instance of sustained and dependable underground water supply.

"The source of the large Fall River springs is difficult to determine. Surface topography is of little value as a guide in delimiting the catchment area." That the actual drainage area is greater than the area indicated by surface topography, which is only about 600 square miles, or approximately 400,000 acres, is clear from the following: The average precipitation over this area is about 24 inches per year, or an aggregate of about 800,000 acre feet, while the discharge from the Fall River springs amounts to upward of 1,000,000 acre feet. When it is realized that frequently not over from one-third to one-half of the precipitation even under favorable conditions appears as stream flow, a better understanding of the true drainage area of Fall River can be had. Instead of being only 600 square miles, as indicated by surface topography, the area probably amounts to from 1,500 to 2,000 square miles, or roughly about three times what surface topography indicates. Substantial corroboration of large drainage to the Fall River basin is evidenced by the fact that the surface drainage of a large area west and north of Happy Camp flows west to the porous lavas and sinks, that Butte and Antelope creeks at the northeast of Mount Shasta sink, and that large seepage losses are known to occur along the south shore of Tule Lake. The report on Iron Canyon project states that "In 1908 and 1909 the Reclamation Service excavated two or three galleries into lava beds at the south shore of Tule Lake and connected with the lake by channels that permitted lake water to flow into them. For many months a constant discharge of about 30 second feet from the lake

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entered these galleries and was absorbed by the lava formation, only terminating by the subsidence of the lake level below the level of the galleries.

All indications along the south shore of Tule Lake, and even of Clear Lake east of Tule Lake, point to an extremely porous structure and to general sub-surface flows in a southerly direction. South of these lakes the lava beds rise to the summit of Glass Mountain, an elevation of about 8,000 feet. Due to elevation and location, precipitation at this point is very considerable and the mountain carries snow practically all of the year. In spite of this there are no surface streams at any time of the year in the territory southeast of Tule Lake and around and including Glass Mountain. It is probable, therefore, that a large portion of the northeastern and eastern drainage of Shasta and territory within the valleys of Butte Creek, Lower Klamath Lake and Tule Lake as well as territory immediately north of the Fall River springs contributes to this great underground flow.

These immense volcanic deposits constitute in themselves a subterranean reservoir from which issue the Fall River springs. The spring flow is almost constant at all seasons and years, indicating unmistakably a vast storage which alone could equalize the natural fluctuations in accretions to the underground water supply. The Fall River springs, although extending along a front of several miles, issue at practically the same elevation without pressure and in a manner to forcibly impress one with the conviction that they act merely as a spillway from some great underground reservoir which probably reaches for many miles, possibly for many dozen miles, northerly from the springs under the lava beds of Glass Mountain."

Plateau Areas. These areas consist generally of broad, flat, or slightly rolling lava flows overlaid with a mantle of 2 to 5 feet of adobe, with the surface very generally covered with loose angular lava fragments varying from a few inches to a foot or more in size. The only vegetation over the greater part of these areas is a light growth of grass, sage brush and scattering juniper, all indicative of scanty precipitation. Such names as the "Devil's Garden" and "Rocky Prairie" have aptly been given to portions of the plateau. Northwest of Canby there is a zone of relatively high precipitation referred to in the preceding section entitled, "Zone of Heavy Precipitation Easterly from Mt. Shasta." This supports a fair stand of timber, but its soil conditions do not differ materially from other bench areas. The average precipitation over the plateau varies generally from 14 to 18 inches, most of which falls as snow during winter. The larger part of this precipitation is readily absorbed and held by the adobe capping, resulting in a very saturated condition of soil that frequently obtains during winter and early spring.

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After the point of saturation is reached additional precipitation or melted snow yields some small surface run-off. There is no evidence to indicate that percolating waters pass entirely through the adobe mantle in any appreciable quantity. In fact the absence of spring flow around the base of the adobe capped plateau areas is quite conclusive that the adobe, while having great retentive capacity, effectively prevents penetration to the underlying lavas.

With an annual evaporation rate over these areas of about three feet in depth, and an average precipitation of less than one-half that amount, it may be concluded with practical certainty that under ordinary conditions the greater part of the precipitation, probably upwards of three-quarters, is held by the soil until evaporated. In years of heavy snow-fall followed by wind and high temperatures or rainfall conditions tending to very rapid melting of the snow, excessive run-off results, sometimes causing short-lived but severe floods in the Pit valleys.

As illustrating the above, Willow Creek drains about 550 square miles above the outlet of Clear Lake Reservoir. All of this territory may be classed as plateau area. It includes a part of the zone of relatively high precipitation previously referred to. Indications are that the average annual precipitation is about 18 inches, the amount differing from season to season. Records of run-off for 1905 to 1914 as measured by the U. S. Reclamation Service at Clear Lake show an average yield of 130,000 acre feet, equal to 4.4 inches depth on the drainage area, or about 25 per cent of the precipitation. This yield fluctuated between 1.2 inches in 1908, and 8.6 inches in 1907.

It is to be noted that both the precipitation and run-off on the Willow Creek drainage area as indicated by forest cover, elevation and slope are probably greater than on most of the plateau areas of the Pit, the average annual run-off of the latter probably ranging from 3 to 4 inches in depth of the tributary watershed, and in dry years not over 1 inch may be expected. Such dry years may be looked for about one year in five.

STREAM FLOW DATA.

Gaging Stations (see Plate 7). A gaging station on McCloud River has been maintained by the U. S. Geological Survey almost continuously since October, 1902. Early in 1904 stations were established at the various damsites that had been located by the Reclamation Service in the Pit River Basin, viz, on South Fork at Jess Valley, on West Valley Creek in West Valley, on the Pit at Canby and at Bieber, and on Ash Creek at Adin. These stations were maintained for about two years, except at Bieber, where measurements for about six years were taken. Subsequently the U. S. Geological Survey established stations on the

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Pit at Henderson and Ydalpom, on Fall River at Fall River Mills, on Hat Creek at Hat Creek and at the Hawkins Ranch, on Rising River two miles south of Cassel, on Burney Creek above Burney, on Kosk Creek near Henderson, on Montgomery Creek at Montgomery Creek, and on Squaw Creek near Ydalpom. Likewise stations of importance to the purposes of this report were established at Drews, Cottonwood, Thomas; and Dog Creeks in the Goose Lake Basin.

Details of summarized records of stream flow as given by the U. S. Geological Survey in Water Supply Papers 298 and 331, also in advance statistics not yet published, at all points in the basin, follow. Miscellaneous measurements of streams and ditches, valuable mainly in connection with local uses of water for irrigation, are given in the chapter on "Present Appropriations and Uses of Water."

The above records are unsatisfactory in the fact that the periods over which they extend are insufficiently long to establish reliable averages. The measurements of flow of Sacramento River at Red Bluff extend however over 19 years, therefore the Pit River records have been extended and enlarged by analogy in a study of all of the flows in the region.

Flow of Pit River at Big Valley (quoting from the Iron Canyon Report). The flow of Pit River at Big Valley was measured during a six-year period, from 1904 to 1908, inclusive, and during 1913–14. It averaged during that period 728,750 acre feet annually, the maximum being 1,400,000 acre feet, and the minimum 187,000 acre feet. During the same period the Sacramento River at Red Bluff averaged 12,104,000 acre feet per annum, or 23 per cent more than its flow averaged during a 19-year period which included these six years. If the flow of the Pit at Big Valley for these six years be reduced 23 per cent to correspond with the correction required at Red Bluff, the average run-off of Pit River thus corrected would be 561,000 acre feet, still a very substantial amount. The character of the watershed would not, however, warrant the use of such a ratio in deducing the corrected flow. A comparison of flows on the Sacramento at Red Bluff and the Pit at Big Valley furnishes the following data:

Season	Sacramento at Red Bluff, acre feet	Pit at Big Valley, acre feet	Ratio
1903–04	15,900,000	1,400,000	100:8.8
1904–05	10,600,000	303,000	100:2.9
1905–06	11,100,000	755,000	100:6.8
1906–07	13,700,000	1,110,000	100:8.0
1907–08	7,720,000	187,000	100:2.4
1913–14*	†13,600,000	617,000	100:4.5

*Records not complete. Portion of year estimated.
†Actual record later available shows 13,500,000 acre feet.

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The annual discharge of Pit River thus ranged from 2.4 per cent to 8.8 per cent of the Sacramento flow, the lower percentages corresponding with the seasons of lower flow at Red Bluff. This is as would be expected, because the steady perennial flows of the Sacramento and Pit —derived from deep-seated springs which in dry years constitute so large a proportion of the entire discharge—have their source down stream from Big Valley. The watershed of Pit River tributary to Big Valley, as determined by surface contours, is 4,040* square miles and of the Sacramento at Red Bluff 10,400* square miles, the ratio being about 10:4* while the ratio of run-off runs between 10:0.8 and less. The watershed of the Pit tributary to Big Valley is, as before stated, mainly of volcanic origin, and except for the higher mountain areas is arid in character. In dry years the late summer flows of the Pit at Big Valley wholly fail or are entirely used for irrigation in that valley. Under such conditions it is plain the proportionate contribution of Pit River above Big Valley to the entire flow of the Sacramento at Red Bluff would during dry years be very much less than during wet years, when the surface run-off from rains or melting snows on the great watershed above Big Valley would enter the Pit and its tributaries in appreciable volume. The recorded variation in the ratio of discharges from 2.4 per cent to 8.8 per cent appears, therefore, consistent and reasonable under the natural conditions known to exist. A curve of ratios between annual discharges at Red Bluff and Big Valley has therefore been constructed for application to the years when the run-off of the former was known but the latter was not, in order that a correction based on known conditions could be applied to the Red Bluff records to establish reasonable estimates of Big Valley flows during the years for which no records exist. The ratio between Red Bluff and Big Valley flows has been taken as follows:

	Acre feet	Percentage of discharge originating in Pit River above Big Valley
Annual discharge at Red Bluff	5,000,000	1.2
Annual discharge at Red Bluff	6,000,000	1.5
Annual discharge at Red Bluff	7,000,000	1.8
Annual discharge at Red Bluff	8,000,000	2.3
Annual discharge at Red Bluff	9,000,000	2.8
Annual discharge at Red Bluff	10,000,000	3.5
Annual discharge at Red Bluff	11,000,000	4.1
Annual discharge at Red Bluff	12,000,000	5.0
Annual discharge at Red Bluff	13,000,000	6.0
Annual discharge at Red Bluff	14,000,000	7.0
Annual discharge at Red Bluff	15,000,000	8.0
Annual discharge at Red Bluff	16,000,000	9.0

*NOTE.—These figures include Goose Lake drainage area. If these are excluded the areas will be 2,950 and 9,300 square miles, respectively, and the ratio will be 10:3.

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By applying the above percentages to all years on record at Red Bluff we obtain the following estimates of discharges at Big Valley.

Season	Flow at Red Bluff, acre feet	Percentage correction to apply	Estimated discharge of Pit River at Bieber, acre feet
1895-96	10,200,000	3.6	*367,000
1896-97	10,200,000	3.6	*367,000
1897-98	4,960,000	1.2	*60,000
1898-99	5,800,000	1.5	*87,000
1899-1900	8,530,000	2.5	*213,000
1900-01	8,840,000	2.7	*239,000
1901-02	11,300,000	4.4	*497,000
1902-03	9,760,000	3.2	*302,000
1903-04	15,900,000	8.8	†1,400,000
1904-05	10,600,000	2.9	†308,000
1905-06	11,100,000	6.8	†755,000
1906-07	13,700,000	8.0	†1,110,000
1907-08	7,720,000	2.4	†187,000
1908-09	13,400,000	6.4	*858,000
1909-10	8,910,000	2.7	*241,000
1910-11	9,910,000	3.4	*337,000
1911-12	6,370,000	1.6	*102,000
1912-13	6,430,000	1.6	*103,000
1913-14	13,600,000	4.5	‡617,000
Average 19 years[1]	9,860,000	4.4	429,000

*Estimate.
†Actual record.
‡Mostly actual record.
[1]NOTE.—There is an error in the above record for 1895-96, and some little additional data has been obtained, but these do not materially affect the above.

The above table of flows of the Pit at Big Valley taken in conjunction with the known local peculiarities of the catchment area, emphasizes and explains the flashy character of the stream flow above the junction with Fall River, and its liability to drouth. This part of the watershed contains vast tracts of the plateau area previously referred to, which furnish minimum yields in normal seasons, and in wet seasons readily shed the surplus.

Thus during a year of normal flow on the Sacramento, with a discharge of about 10,000,000 acre feet at Red Bluff, the Pit at Bieber only discharges about 3.4 per cent of this, or about 340,000 acre feet, an amount only about three quarters of its average flow, while in wet seasons like 1904, when the Sacramento only exceeded its normal flow by about 60 per cent, the Pit exceeded its normal by about 200 per cent. Again in a year like 1898, when the Sacramento had a yield of about 50 per cent of its normal, the Pit apparently only furnished about 14 per cent of its normal.

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Pit River near Canby, California.

Location—One-half mile above Warm Springs Valley damsite, at highway bridge, three and one-half miles southwest of Canby.

Records available—January 1, 1904, to December 31, 1905.

Drainage area—About 1,500 square miles.

Diversions—Water diverted from main stream and tributaries, above the station, for irrigation.

Accuracy—Fair.

Monthly Discharge of Pit River near Canby, California.

(Drainage area 1,500 square miles.)

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1904				
January	205	110	135	8,300
February	7,340	115	2,140	123,000
March	17,000	1,680	4,210	259,000
April	3,770	1,190	1,680	100,000
May	5,620	1,190	2,080	128,000
June	1,160	205	594	35,300
July	185	76	135	8,300
August	76	12	43	2,640
September	34	8	15	893
The period				665,000
1904-05				
October	130	34	91	5,600
November	148	130	131	7,800
December	795	76	188	11,600
January	1,190	132	443	27,200
February	1,370	206	533	29,600
March	965	206	479	29,500
April	1,340	87	510	30,300
May	269	34	165	10,100
June	226	87	151	8,980
July	87	47	61.7	3,790
August	24	1.5	6.4	394
September	16	3.5	5.6	333
The year	1,370	1.5	230	165,000
1905				
October	64	16	45.4	2,790
November	148	64	92.2	5,490
December	148	87	118	7,260

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Pit River near Bieber, California.

Location—At Big Valley damsite, 12 miles south of Bieber.

Records available—January 22, 1904, to September 30, 1908, and December 18, 1913, to August 11, 1914.

Drainage area—About 2,950 square miles.

Diversions—Water is diverted from the main streams and tributaries, above the station, for irrigation.

Accuracy—Fair.

Monthly Discharge of Pit River near Bieber, California.

(Drainage area 2,950 square miles.)

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1904				
January			[1]238	14,600
February	13,700	180	3,950	227,000
March	18,300	2,820	7,590	467,000
April	6,500	2,950	4,210	251,000
May	8,320	1,600	3,440	212,000
June	1,600	96	542	32,300
July	120	57	83	5,100
August	57	10	33	2,030
September	38	12	16	952
The period				1,210,000
1904-05				
October	220	28	105	6,330
November	270	120	165	9,820
December	1,400	96	304	18,700
January	2,960	213	1,040	64,000
February	2,270	349	1,060	60,000
March	2,270	349	1,100	67,600
April	2,660	147	950	56,500
May	270	109	166	10,200
June	190	44	103	6,130
July	92	29	51.8	3,190
August	29	2.2	9.85	606
September	2.2	.8	1.23	73
The year	2,960	.8	423	303,000
1905-06				
October	44	2.2	15.4	947
November			[1]91	5,410
December			[2]210	12,900
January			[1]1,280	78,700
February	3,840	900	1,930	107,000
March	13,800	2,120	4,640	285,000
April	7,360	1,280	2,590	154,000
May	1,230	825	948	58,300
June	755	190	544	32,400
July			[1]251	15,400
August	108	21	50.8	3,120
September	29	21	23.8	1,420
The year			1,050	755,000

[1]Partly estimated.

[2]Estimated by comparison with other Pit River stations.

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Monthly Discharge of Pit River near Bieber, California—Continued.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1906–07				
October			[1]44.5	2,740
January	3,220	177	710	43,700
February	11,600	1,600	4,190	233,000
March	27,500	2,240	6,940	427,000
April	3,520	1,800	2,970	177,000
May	2,230	900	1,130	69,500
June	3,520	825	2,160	129,000
July	825	120	323	19,900
August	120	45	71.7	4,410
September	57	45	51.5	3,060
The period				1,110,000
1907–08				
October	258	57	113	6,950
November	450	205	307	18,300
December	1,140	400	799	49,100
January	2,010	177	861	52,900
February	900	120	339	19,500
March	450	135	322	19,800
April	205	29	77.6	4,620
May	127	29	83.3	5,120
June	127	66	85.6	5,090
July	96	26	68.3	4,200
August	29	5	9.3	572
September	6	4	4.8	286
The year	2,010	4	256	187,000
1913–14				
December 18 to 31	1,080	110	295	8,190
January	9,880	850	3,500	215,000
February	3,680	745	1,830	102,000
March	3,520	1,240	2,370	146,000
April	1,900	850	1,440	85,700
May	850	142	323	19,900
June	850	142	192	11,400
July	470	56	75.0	4,610
August 1 to 11	142	22	32.6	711
September	47	24		
The period				594,000

[1]Partly estimated.

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Pit River at Henderson, California.

Location—At Big Bend Ferry, one-fourth mile above Henderson post office, in Sec. 36, T. 37 N., R. 1 W. Nelson Creek enters half a mile above and Kosk Creek one mile below the station.

Records available—September 28, 1910, to September 30, 1914.

Drainage area—Not measured.

Gage—Vertical staff on an alder tree on left bank about 100 feet above ferry.

Channel—Small boulders and coarse gravel; fairly permanent.

Discharge measurements—Made from car and cable 80 feet below gage.

Accuracy—Sufficient discharge measurements have not been made to define the rating curve at medium and high stages.

Monthly Discharge of Pit River at Henderson, California.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1910-11				
November 15 to 30			3,160	100,000
December	4,730	3,190	3,820	235,000
January	6,010	3,020	3,530	217,000
February	7,190	3,550	5,290	294,000
March	13,200	3,550	8,260	508,000
April	10,200	5,360	7,380	439,000
May	5,790	4,330	5,130	315,000
June	4,290	3,370	3,760	224,000
July	3,370	3,020	3,220	198,000
August	3,020	2,850	2,990	184,000
September	3,020	2,850	2,970	177,000
The period				2,890,000
1911-12				
October	3,060	3,020	3,020	186,000
November	3,190	3,100	3,190	190,600
December	3,190	3,020	3,100	191,000
January	4,940	3,020	3,530	217,000
February	3,740	3,020	3,400	196,000
March	3,930	3,020	3,490	215,000
April	3,740	3,020	3,360	200,000
May	4,530	3,020	3,690	227,000
June	3,370	2,850	3,010	179,000
July	3,020	2,690	2,910	179,000
August	2,850	2,690	2,710	167,000
September	2,850	2,690	2,700	161,000
The year	4,940	2,690	3,170	2,310,000
1912-13				
October	2,850	2,690	2,780	171,000
November	3,190	2,850	3,030	181,000
December	3,190	2,850	3,000	184,000
January	3,290	2,780	2,930	180,000
February	3,290	2,940	3,090	172,000
March	5,400	3,020	3,940	242,000
April	7,600	3,950	4,950	295,000
May	3,950	2,940	3,490	215,000
June	3,020	2,780	2,870	171,000
July	3,110	2,700	2,830	174,000
August	3,020	2,560	2,760	170,000
September	2,630	2,490	2,560	152,000
The year	7,600	2,490	3,180	2,310,000

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Monthly Discharge of Pit River at Henderson, California—Continued.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1913-14				
October	2,630	2,560	2,610	160,000
November	2,780	2,630	2,710	161,000
December	8,100	2,700	3,040	187,000
January	12,000	4,760	7,680	472,000
February	9,690	4,050	5,840	324,000
March	8,420	6,060	7,080	435,000
April	7,600	5,180	6,250	372,000
May	5,180	3,660	4,280	263,000
June	3,660	3,110	3,370	201,000
July	3,110	2,860	2,950	181,000
August	2,850	2,770	2,840	175,000
September	2,850	2,770	2,810	167,000
The year	12,000	2,560	4,280	3,100,000

Pit River near Ydalpom, California.

Location—At Silverthorne Ferry, in the N.W. ¼ Sec. 32, T. 34 N., R. 3 W., 1½ miles southwest of Ydalpom and 7½ miles above junction with Sacramento River. Squaw Creek enters half a mile above and McCloud River 4 miles below the station.

Records available—November 16, 1910, to September 30, 1914.

Drainage area—6,350 square miles.*

Gage—Vertical staff on an ash tree on left bank 350 feet below ferry.

Channel—Gravel and sand, and appears permanent.

Discharge measurements—Made from car and cable 50 feet above ferry cable.

Diversion—Water is diverted from the main stream and tributaries, above the station, for irrigation.

Accuracy—Rating curve well defined and results are good.

Monthly Discharge of Pit River near Ydalpom, California.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1911-12				
October	3,220	3,080	3,170	195,000
November	3,440	3,150	3,300	196,000
December	3,220	3,220	3,220	198,000
January	13,900	3,220	4,760	293,000
February	6,000	3,820	4,560	262,000
March	8,120	3,820	5,270	324,000
April	7,320	3,980	4,440	264,000
May	8,330	3,980	5,270	324,000
June	4,620	3,370	3,680	219,000
July	3,370	2,950	3,140	193,000
August	2,950	2,830	2,880	177,000
September	3,820	2,830	3,000	179,000
The year	13,900	2,830	3,890	2,820,000

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Monthly Discharge of Pit River near Ydalpom, California—Continued.

1912-13				
October	3,020	2,740	2,810	173,000
November	7,520	3,030	3,730	222,000
December	6,360	3,030	3,820	235,000
January	18,400	3,330	5,490	338,000
February	4,770	4,100	4,550	253,000
March	7,520	3,940	5,560	342,000
April	10,100	5,110	6,980	415,000
May	5,460	3,780	4,680	288,000
June	3,940	3,300	3,470	206,000
July	3,480	3,030	3,170	195,000
August	3,330	2,740	2,960	182,000
September	2,740	2,740	2,740	163,000
The year	18,400	2,740	4,160	3,010,000
1913-14				
October	2,740	2,740	2,740	168,000
November	6,550	2,740	4,680	278,000
December	33,900	3,030	4,600	283,000
January	32,800	8,750	17,500	1,080,000
February	31,800	6,000	10,500	583,000
March	11,500	7,520	9,910	609,000
April	15,300	7,320	10,100	601,000
May	7,120	4,600	5,530	340,000
June	5,280	3,630	4,150	247,000
July	4,260	3,030	3,470	213,000
August	3,030	2,740	2,800	172,000
September	2,880	2,740	2,800	167,000
The year	33,900	2,740	6,540	4,740,000

*As given in W. S. Paper 331, including Goose Lake Basin. Should be reduced to 1,250 square miles.

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South Fork of Pit River near Ivy, California.

Location—Near Jess Valley damsite, in Sec. 10, T. 39 N., R. 14 E., about 12 miles east of Likely.

Records available—January 11, 1904, to November 15, 1905.

Drainage area—91 square miles.

Diversion—Water is diverted from the tributaries above for irrigation.

Accuracy—Poor.

Monthly Discharge of South Fork of Pit River near Ivy, California.

	Discharge in second-feet		Run-off	
	Mean	Per square mile	Depth in inches on drainage area	Total in acre feet
1904				
January	[1]30	0.330	0.38	1,840
February	76	.835	.90	4,370
March	82	.901	1.04	5,040
April	90	.989	1.10	5,360
May	372	4.09	4.72	22,900
June	234	2.57	2.87	13,900
July	85	.934	1.08	5,230
August	46	.505	.58	2,830
September	35	.385	.43	2,080
The period				63,600
1904-05				
October	47	.516	.59	2,890
November	41	.451	.50	2,440
December	39	.429	.49	2,400
January	38	.418	.48	2,340
February	44	.484	.50	2,440
March	66	.725	.84	4,060
April	90	.989	1.10	5,360
May	150	1.65	1.90	9,220
June	120	1.32	1.47	7,140
July	34	.374	.43	2,090
August	25	.275	.32	1,540
September	15	.165	.18	893
The year	59.1	.649	8.80	42,800
1905				
October	14	.154	.18	861
November	20	.220	.25	1,190
December	30	.330	.38	1,840

[1]Mean of 21 days. Assumed as mean for entire month.

NOTE—These values were obtained by interpolation between discharge measurements and by hydrograph comparison with other Pit River stations. They are only an approximate estimate of the monthly flow and should be used with caution.

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West Valley Creek near Likely, California.

Location—At West Valley damsite, near outlet of West Valley, about two miles above junction with South Fork, and seven miles east of Likely.

Records available—January 11, 1904, to December 31, 1905.

Diversions—Water diverted above for irrigation.

Accuracy—Poor gage read one to five times a month.

Monthly Discharge of West Valley Creek near Likely, California.

	Mean discharge in second-feet	Run-off (total in acre-feet)
1904[1]		
January	20	1,230
February	100	5,750
March	70	4,300
April	75	4,460
May	115	7,070
June	50	2,980
July	20	1,230
August	20	1,230
September	12	714
The period		29,000
1904-05[2]		
October	20	1,230
November	20	1,190
December	30	1,840
January	23.5	1,440
February	23.6	1,310
March	32	1,970
April	31.2	1,860
May	24.8	1,520
June	29.3	1,740
July	16.8	1,030
August	14.3	879
September	18.7	1,110
The year	23.7	17,100
1905[2]		
October	14.4	885
November	16.1	958
December	25	1,540

[1]The gage heights recorded in 1904 were unreliable and have not been republished. Monthly estimates of flow for 1904 are based on the discharge measurements and are only approximate. They should be used with caution.

[2]Monthly estimates for 1905 are better than for 1904. Accuracy value for 1905 may be classed as follows: January to August, B; September and October, C; November and December, D.

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Ash Creek at Adin, California.

Location—Near Round Valley damsite at Adin.

Records available—March 13, 1904, to December 31, 1905.

Drainage area—260 square miles.

Diversions—Water diverted above for irrigation.

Accuracy—Fair.

Monthly Discharge of Ash Creek at Adin, California.
(Drainage area 260 square miles.)

	Discharge in second-feet			Run-off (total in acre-feet)
	Maximum	Minimum	Mean	
1904				
March, 13-31	1,470	488	735	27,700
April	785	416	550	32,700
May	885	335	505	31,100
June	335	50	70.8	4,510
July	45	35	39.8	2,450
August	31	28	30.1	1,850
September	42	31	33.2	1,980
The period				102,000
1904-05				
October	42	29	31.6	1,940
November	36	31	31.8	1,890
December	400	31	55.5	3,410
January	314	41	107	6,580
February	526	56	158	8,780
March	120	80	214	13,200
April	526	106	176	10,500
May	72	41	56.7	3,490
June	41	27	32.8	1,950
July	27	14	15.5	953
August	27	14	20.5	1,260
September	41	20	27.2	1,620
The year	1,120	14	77.2	55,600
1905				
October	41	27	31.1	1,910
November	41	34	37.5	2,230
December	34	34	34.0	2,090

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Fall River at Fall River Mills, California.

Location—At highway bridge at Fall River Mills, in Sec. 31, T. 37 N., R. 5 E., about 600 feet above junction with Pit River.

Records available—January 19, 1912, to September 30, 1913.

Drainage area—Not given.

Gage—Vertical staff fastened to downstream end of left abutment of bridge.

Channel—Solid rock and gravel.

Discharge measurements—Made from upstream side of bridge.

Accuracy—As the area drained consists largely of lavas, run-off is very uniform throughout the year. Results are good.

Monthly Discharge of Fall River at Fall River Mills, California.

	Discharge in second-feet			Run-off (total in acre-feet)
	Maximum	Minimum	Mean	
January 19-31	1,570	1,460	1,520	39,200
February	1,520	1,410	1,460	84,000
March	1,520	1,461	1,470	90,400
April	1,520	1,460	1,480	88,100
May	1,570	1,410	1,480	91,000
June	1,460	1,410	1,440	85,700
July	1,460	1,410	1,430	87,900
August	1,460	1,410	1,430	87,900
September	1,520	1,410	1,470	87,500
The period				742,000
1912-13				
October	1,460	1,410	1,420	87,300
November	1,460	1,410	1,460	86,900
December	1,460	1,410	1,440	88,500
January	1,440	1,240	1,380	84,800
February	1,460	1,380	1,430	79,400
March	1,490	1,380	1,410	86,700
April	1,540	1,380	1,450	86,300
May	1,590	1,430	1,500	92,200
June	1,430	1,320	1,370	81,500
July	1,490	1,320	1,360	83,600
August			1,330	81,800
September			[1]1,280	76,200
The year			1,400	1,020,000

[1]Estimated on basis of measurement, September 15, 1913. Gage height 1.81; discharge 1,280 second-feet.

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Hat Creek at Hawkins Ranch, near Hat Creek, California.

Location—At Hawkins ranch, in Sec. 5, T. 33 N., R. 5 E., 6 miles south of Hat Creek.

Records available—August 15, 1911, to September 30, 1913.

Drainage area—Not measured.

Gage—Vertical staff on downstream end of right support of footbridge.

Channel—Fairly smooth and probably permanent.

Discharge measurements—Made from footbridge.

Diversions—The only important diversion for irrigation above the station is the H. M. Wilcox ditch, which heads about one-half mile above the gage. About 40 second-feet is diverted by this canal at irregular intervals, as shown by the observer's notes. Near the source of the creek water is diverted into Bear Creek drainage for use in power development.

Monthly Discharge of Hat Creek at Hawkins Ranch, near Hat Creek, California.

	Discharge in second-feet			Run-off (total in acre-feet)
	Maximum	Minimum	Mean	
1911				
August			150	5,060
September			184	10,900
1911-12				
October	224	174	207	12,700
November	213	213	213	12,700
December	213	191	198	12,200
January	195	191	193	11,900
February	191	180	184	10,600
March	180	174	178	10,900
April	180	174	178	10,600
May	217	153	183	11,300
June	257	170	197	11,700
July	191	166	174	10,700
August	191	153	170	10,500
September	257	187	206	12,300
The year	257	153	190	138,000
1912-13				
October	213	191	202	12,400
November	235	180	205	12,200
December	170	149	157	9,650
January	160	132	146	8,980
February	132	128	133	7,390
March	166	128	137	8,420
April	166	132	146	8,690
May	213	160	181	11,100
June	235	132	176	10,500
July	138	111	125	7,690
August	138	111	132	2,360
The period				99,400

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Hat Creek at Hat Creek, California.

Location—At private highway bridge on Morris Ranch, in the Lassen National Forest, in the S.E.¼ Sec. 10, T. 34 N., R. 4 E., M.D.M., 1 mile north of Hat Creek post office. (Post office moved during 1912.)

Records available—September 22, 1910, to September 30, 1912.

Drainage area—Not measured.

Gage—Vertical staff fastened to downstream end of right abutment of bridge.

Channel—Gravel and small boulders; apparently permanent.

Discharge measurements—Made from downstream side of bridge.

Diversions—On account of the diversions for irrigation above the station this record does not show the natural run-off from the drainage basin. On May 13, 1911, the nine ditches were diverting a total of 110 second feet. Of this amount, it was estimated that 55 second-feet was returned to the stream above the gage.

Accuracy—Rating curve fairly well defined; results fair.

Cooperation—Gage-height record furnished by U. S. Forest Service.

Monthly Discharge of Hat Creek at Hat Creek, California.

	Discharge in second-feet			Run-off (total in acre-feet)
	Maximum	Minimum	Mean	
1910-11				
November	153	140	144	8,570
December	238	140	163	10,000
January	170	140	149	9,160
February	160	138	144	8,000
March	149	134	137	8,420
April	160	140	153	9,100
May	142	90	116	7,130
June	244	123	194	11,500
July	218	86	167	10,300
August	98	68	79.4	4,880
September	125	94	109	6,490
The period				93,600
1911-12				
October	165	132	158	9,720
November	167	160	164	9,760
December	165	160	161	9,900
January	205	162	170	10,500
February	167	149	160	9,200
March	158	145	153	9,410
April	156	102	129	7,680
May	138	84	117	7,190
June	153	102	128	7,620
July	105	52	85.8	5,280
August	110	57	86.3	5,310
September	160	112	132	7,860
The year	205	52	137	99,400

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Rising River near Cassel, California.

Location—At highway bridge in Sec. 8, T. 35 N., R. 4 E., about half a mile above junction with Hat Creek and 1½ miles south of Cassel.

Records available—August 15, 1911, to September 30, 1913.

Drainage area—Not measured.

Gage—Vertical staff on downstream side of bridge pier near left bank.

Channel—Sand and gravel and is fairly permanent.

Discharge measurements—Made from upstream side of bridge.

Accuracy—Results are excellent. This stream, which is only about 2 miles long, is fed by springs, and its flow is very constant.

Monthly Discharge of Rising River near Cassel, California.

	Discharge in second-feet			Run-off (total in acre-feet)
	Maximum	Minimum	Mean	
1911				
August	490	460	465	15,700
September	465	460	462	27,500
1911-12				
October	465	418	446	27,400
November	431	418	420	25,000
December	418	404	412	25,300
January	440	381	400	24,600
February	381	361	374	21,500
March	373	337	352	21,600
April	337	329	332	19,800
May	337	315	329	20,200
June	373	337	362	21,500
July	381	353	364	22,400
August	408	353	370	22,800
September	440	395	418	24,900
The year	465	315	382	277,000
1912-13				
October	460	420	447	27,500
November	460	400	432	25,700
December	400	360	381	23,400
January	360	340	349	21,500
February	340	320	326	18,100
March	320	305	306	18,800
April	309	290	298	17,700
May	305	275	292	18,000
June	380	305	344	20,500
July	380	340	349	21,500
August	----------	----------	340	20,900
September	----------	----------	[1]335	19,900
The year	----------	----------	350	254,000

[1]Estimated on basis of measurement, September 15, 1913. Gage height 1.28 feet; discharge 335 second-feet.

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Burney Creek near Burney, California.

Location—At highway bridge three-fourths of a mile southwest of Burney, in the S.W. ¼ Sec. 19, T. 35 N., R. 3 E., 3 miles above Goose Creek and 10 miles above junction with Pit River.

Records available—August 14, 1911, to September 30, 1912.

Drainage area—Not measured.

Gage—Vertical staff on upstream end of center pier of bridge.

Channel—Gravel and sand; probably permanent.

Discharge measurements—From bridge except at low water, when measurements are made by wading.

Diversions—Two miles above the station about 2 second-feet are diverted for irrigation during the summer months, and about 0.5 second-feet during the remainder of the year.

Accuracy—Rating curve fairly well defined; results fair.

Monthly Discharge of Burney Creek near Burney, California.

	Discharge in second-feet			Run-off (total in acre-feet)
	Maximum	Minimum	Mean	
1911				
August, 14-31	20	16	17.7	632
September	20	17	18.8	1,120
1911-12				
October	28	20	23.1	1,420
November	41	22	24.3	1,450
December	26	20	21.5	1,320
January	90	20	31.7	1,950
February	142	33	54.8	3,150
March	99	39	54.7	3,360
April	132	44	62.1	3,700
May	147	75	98.3	6,040
June	78	23	42.3	2,520
July	20	14	16.7	1,030
August	16	14	14.6	898
September	46	13	17.7	1,050
The year	147	13	38.4	27,900

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Kosk Creek near Henderson, California.

Location—Above bridge in Sec. 12, T. 37 N., R. 1. W., on the Holm Ranch, 4 miles north of Henderson, in Shasta National Forest, and 3¼ miles above the mouth of the creek. Baker Creek enters about one-fourth mile below the station.

Records available—October 1, 1910, to September 30, 1913.

Drainage area—51.9 square miles.

Gage—Vertical staff on an alder tree on left bank 100 feet above bridge.

Channel—Gravel and small boulders; fairly permanent.

Discharge measurements—Made from bridge or by wading.

Accuracy—Results are good.

Cooperation—Gage-height record furnished by U. S. Forest Service.

Monthly Discharge of Kosk Creek near Henderson, California.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1910-11				
October	39	28	30.9	1,900
November	293	22	55.1	3,280
December	1,500	60	253	15,600
April	2,300	584	1,020	60,700
May	1,200	400	625	38,400
June	398	134	230	13,700
July	132	56	88.9	5,470
August	56	45	51.8	3,190
September	45	42	42.2	2,510
1911-12				
October	41	33	33.5	2,060
November	33	33	33	1,960
December	33	29	30.3	1,860
April	600	166	221	13,200
May	843	248	378	23,200
June	310	101	174	10,400
July	97	53	69.9	4,300
August	52	36	40.7	2,500
September	43	37	40.2	2,390
1912-13				
October	41	36	39.2	2,410
November	465	40	103	6,130
December	205	65	91	5,600
January	154	83	111	6,820
February	207	146	177	9,830
March	345	147	181	11,100
April	623	391	469	27,900
May	523	189	322	19,800
June	194	80	121	7,200
July	93	57	73.1	4,490
August	80	46	51.1	3,140
September	41	28	34.4	2,050
The year	623	28	147	106,000

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Montgomery Creek at Montgomery Creek, California.

Location—At highway bridge in Sec. 36, T. 35 N., R. 1 W., about one-fourth mile south of Montgomery Creek post office, and 2 miles above junction with Pit River.

Records available—August 11, 1911, to September 30, 1913.

Drainage area—Not measured.

Gage—Vertical staff on a large alder tree on left bank 70 feet below the bridge.

Channel—Small boulders and gravel and is rough.

Discharge measurements—Made from highway bridge or by wading.

Diversions—About 5 miles above the station the Terry Lumber Company diverts water from this stream into Little Cow Creek. During the logging season, from June to December, this diversion is from 8 to 10 second feet. For the remainder of the year the amount is reduced to about 6 second feet.

Accuracy—High water rating curve not well defined; otherwise the records are excellent.

Monthly Discharge of Montgomery Creek at Montgomery Creek, California.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1911				
August, 11-31	23	20	22.0	914
September	23	20	20.4	1,210
1911-12				
October	24	21	21.7	1,330
November	25	21	21.7	1,290
December	28	20	21.4	1,320
January	542	23	66.9	4,110
February	85	38	53.3	3,070
March	110	38	63.2	3,890
April	103	49	58.7	3,490
May	110	54	76.8	4,720
June	66	34	47.7	2,840
July	33	20	24.8	1,520
August	21	18	18.9	1,160
September	91	17	23.3	1,390
The year	542	17	41.5	30,100
1912-13				
October	26	17	18.8	1,160
November	232	19	51.6	3,070
December	102	24	42.8	2,630
January	154	35	56.3	3,460
February	75	47	58.1	3,230
March	110	44	61.8	3,800
April	163	110	128	7,620
May	130	62	94.1	5,790
June	79	35	45.2	2,690
July	38	20	26.5	1,630
August	19	16	17.9	1,110
September	16	14	14.4	857
The year	232	14	51.1	37,000

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Squaw Creek near Ydalpom, California.

Location—At the highway bridge in Sec. 29, T. 34 N., R. 3 W., three-fourths of a mile southwest of Ydalpom (Copper City), and three-fourths of a mile above junction with Pit River.

Records available—October 4, 1911, to September 30, 1913.

Drainage area—Not measured.

Gage—Vertical staff on downstream end of right pier of bridge.

Channel—Gravel and cobblestones; will probably shift slightly at high stages.

Discharge measurements—Made from the bridge or by wading.

Diversions—One small ditch diverts water for irrigation above the station.

Accuracy—High-water rating curve not well defined; otherwise the record is excellent.

Monthly Discharge of Squaw Creek near Ydalpom, California.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1911–12				
October 4–31	76	24	35.5	1,970
November	114	34	42	2,500
December	76	24	38	2,340
January	3,850	34	491	30,200
February	564	178	351	20,200
March	1,890	178	621	38,200
April	1,970	200	359	21,400
May	1,970	224	499	30,700
June	330	135	211	12,600
July	114	34	67.7	4,160
August	34	24	30.1	1,850
September	200	24	48.2	2,870
The period				169,000
1912–13				
October	94	34	39.9	2,450
November	1,030	46	263	15,600
December	1,450	60	266	16,400
January	7,190	156	963	59,200
February	690	163	404	22,400
March	1,090	194	365	22,400
April	930	268	510	30,300
May	335	153	224	13,800
June	218	83	119	7,080
July	61	37	44	2,700
August 1–10	37	32	35.5	704
The period				193,000

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McCloud River near Gregory, California.

Location—At St. Johns Camp near Hirze Mountain, about 14 miles east of Gregory postoffice. Station is 12 to 15 miles above U. S. fishery at Baird postoffice. Station is 15 miles above the mouth of the river.

Records available—October, 1902, to September, 1908.

Channel—Straight, high banks, river bed of limestone with large gravel and boulders.

Discharge measurements—Made from car and cable.

Monthly Discharge of McCloud River near Gregory, California.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1902–03				
October	1,770	1,260	1,350	83,000
November	13,000	1,310	2,830	168,000
December	5,950	1,540	2,570	158,000
January	14,600	1,540	2,880	177,000
February	2,580	1,770	2,040	113,000
March	12,100	2,040	3,740	230,000
April	6,060	2,240	2,810	167,000
May	2,240	1,650	1,910	117,000
June	1,650	1,470	1,540	91,600
July	1,470	1,340	1,370	84,200
August	1,350	1,310	1,320	81,200
September	1,310	1,280	1,300	77,400
The year	14,600	1,260	2,140	1,550,000
1903–04				
October	1,650	1,280	1,320	81,200
November	14,900	1,280	3,430	204,000
December	2,260	1,460	1,830	113,000
January	2,040	1,500	1,650	101,000
February	40,000	1,470	6,000	345,000
March	41,500	3,380	9,390	577,000
April	7,440	4,120	5,470	325,000
May	4,490	3,090	3,760	231,000
June	2,890	1,860	2,220	132,000
July	1,860	1,610	1,750	108,000
August	1,610	1,500	1,570	96,500
September	1,820	1,470	1,510	89,800
The year	41,500	1,280	3,320	2,400,000
1904–05				
October	9,930	1,500	2,700	166,000
November	2,140	1,500	1,640	97,600
December	4,580	1,580	1,840	113,000
January	14,800	1,650	3,890	239,000
February	6,960	2,040	3,280	182,000
March	10,900	2,240	4,070	250,000
April	3,230	2,190	2,490	148,000
May	2,460	1,770	2,110	130,000
June	1,860	1,540	1,600	95,200
July	1,540	1,440	1,490	91,600
August	1,440	1,370	1,400	86,100
September	1,370	1,370	1,370	81,500
The year	14,800	1,370	2,320	1,680,000

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Monthly Discharge of McCloud River near Gregory, California—Continued.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1905-06				
October	1,400	1,340	1,370	84,200
November	1,370	1,340	1,350	80,300
December	1,400	1,370	1,370	84,200
January	9,100	1,370	2,540	156,000
February	5,100	1,500	2,600	144,000
March	12,700	2,140	4,180	257,000
April	7,680	2,580	3,110	185,000
May	10,400	1,860	3,060	189,600
June	10,100	1,950	3,480	207,000
July	1,950	1,540	1,690	104,000
August	1,540	1,440	1,480	91,000
September	1,400	1,400	1,400	83,300
The year	12,700	1,340	2,300	1,660,000
1906-07				
October	1,400	1,370	1,380	84,800
November	2,000	1,370	1,400	83,300
December	5,620	1,340	2,070	127,000
January	16,800	1,470	2,880	177,000
February	18,400	2,140	5,510	306,000
March	30,000	2,460	6,000	369,000
April	5,520	2,580	4,100	244,000
May	2,640	2,040	2,290	141,000
June	2,140	1,650	1,840	109,000
July	1,610	1,470	1,550	95,300
August	1,500	1,400	1,440	88,500
September	1,400	1,370	1,400	83,300
The year	30,000	1,370	2,660	1,910,000
1907-08				
October	1,440	1,370	1,380	84,800
November	1,400	1,370	1,370	81,500
December	2,820	1,370	1,660	102,000
January	6,170	1,580	2,300	141,000
February	4,680	1,690	2,280	131,000
March	2,760	1,770	2,150	132,000
April	2,580	1,770	2,170	129,000
May	2,140	1,690	1,880	116,000
June	1,690	1,400	1,570	93,400
September 12 to 30	1,260	1,180	1,220	46,000

NOTE—Station discontinued June 30, 1908. September gage heights taken on account of extreme low water conditions.

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McCloud River at Baird, California.

Location—at the United States fishery at Baird, in the N.W. ¼ Sec. 23, T. 34 N., R. 4 W., about 2 miles above junction with Pit River. Bailey Creek enters about 2,000 feet above and Johns Creek 2,000 feet below the station.

Records available—December 22, 1910, to September 30, 1914.

Drainage area—665 square miles.

Gage—Vertical staff fastened to an alder tree on right bank, 600 feet above the hatchery.

Channel—Gravel and cobblestones; permanent.

Discharge measurements—Made from car and cable 20 feet above gage.

Accuracy—Rating curve well defined; results excellent.

Cooperation—Gage height record furnished by G. H. Lambson, superintendent of United States fishery.

Monthly Discharge of McCloud River at Baird, California.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1910-11				
December 22 to 31	1,300	1,250	1,270	25,600
January	6,920	1,200	2,150	133,000
February	7,020	1,660	3,160	176,000
March	12,600	1,590	3,800	234,000
April	8,500	2,980	4,060	242,000
May	4,470	2,790	3,260	200,000
June	3,160	1,840	2,440	145,000
July	1,810	1,510	1,650	101,000
August	1,500	1,420	1,450	89,200
September	1,420	1,360	1,390	82,700
The period				1,430,000
1911-12				
October	1,490	1,340	1,380	84,800
November	1,480	1,300	1,350	80,300
December	1,410	1,270	1,290	79,300
January	10,400	1,270	2,230	137,000
February	2,300	1,540	1,800	104,000
March	3,520	1,480	2,250	138,000
April	5,350	1,600	1,910	114,000
May	8,900	2,040	2,930	180,000
June	2,400	1,420	1,770	105,000
July	1,420	1,270	1,340	82,400
August	1,310	1,240	1,260	77,500
September	1,600	1,210	1,260	75,000
The year	10,400	1,210	1,730	1,260,000

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Monthly Discharge of McCloud River at Baird, California—Continued.

	Discharge in second-feet			Run-off (total in acre feet)
	Maximum	Minimum	Mean	
1912-13				
October	1,250	1,150	1,210	74,400
November	5,950	1,150	1,910	114,000
December	3,040	1,250	1,590	97,800
January	10,500	1,360	2,450	151,000
February	2,210	1,480	1,880	104,000
March	2,040	1,480	1,740	107,000
April	3,400	2,120	2,640	157,000
May	3,400	1,810	2,430	149,000
June	1,810	1,360	1,550	92,200
July	1,360	1,250	1,290	79,300
August	1,250	1,150	1,200	73,800
September	1,200	1,150	1,150	68,400
The year	10,500	1,150	1,750	1,270,000
1913-14				
October	1,150	1,150	1,150	70,700
November	4,330	1,150	1,370	81,500
December	23,600	1,150	2,030	125,000
January	24,500	2,400	7,200	443,000
February	22,400	1,880	4,420	245,000
March	4,630	2,820	3,500	215,000
April	10,300	3,160	5,020	299,000
May	3,910	2,400	3,000	184,000
June	2,600	1,810	2,120	126,000
July	1,880	1,480	1,650	101,000
August	1,480	1,360	1,430	87,900
September	1,420	1,400	1,280	76,200
The year	24,500	1,150	2,840	2,050,000

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LAND CLASSIFICATION.

FORESTED AREAS.

Plate 3 shows forested areas in and in the vicinity of the drainage basin of the Pit. Much of the timbered area is mountainous and rocky and its value is almost exclusively confined to the timber products. All this area has, however, a certain value for grazing purposes, and a few areas of quite limited extent appear to have reasonable agricultural possibilities, particularly some 15,000 to 20,000 acres south of Pit River extending west of Hat Creek into Burney Valley.

OPEN RANGE.

The open range consists almost entirely of sage and juniper areas, a large part of which are rocky. The great open plateau, the unforested mountain slopes and to some extent agricultural areas which are not as yet cultivated are used for grazing. The timbered areas are generally of minor grazing value. When the country was first settled little feed for winter use was raised, but the experience of a few hard winters in the early '80s, during which almost all livestock perished, showed the practicable number of cattle to be limited by the supply of hay available for winter feeding. In the past few years the production of hay has overtaken the demand, and in the vicinity of Alturas, where extensive swamp areas have been reclaimed and converted into hay lands, the supply of winter feed appears to be, at least temporarily, in excess of the range capacity. This apparent condition may, however, be somewhat accentuated, due to the reduction in number of cattle resulting from the very favorable prices that have prevailed in the past few years.

Since the establishment of national forest reserves the number of cattle allowed on various portions of the forest range is kept within such limits as will prevent overstocking and destruction of pasturage. A permit is required before the range may be used and a small rental charge is assessed each applicant, the amount depending on the number of livestock and the length of season for which the permit is desired. Outside of the national forests most of the range is in public ownership; nevertheless, considerable areas are patented, especially such as contain springs. Control of such watering places no doubt tends to monopolize the public range and to restrict the number of range cattle.

Cattle are usually turned on the range in April and gathered in during the fall, generally in October. The range season depends on climatic conditions, available feed, etc. Beef cattle are usually shipped to market in the fall, although an increasing number are now fed during winter.

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Hay and alfalfa lands are used for fall pasturage until the first part of December, when the snows usually begin, after which all livestock are fed. The usual practice is to feed 100 head of cattle, including calves, one ton per day. In the average winter season of about four months, one and one fourth tons of hay per animal is fed. The labor cost of feeding is about 50 cents per ton of hay. The price of wild hay usually runs from $4.00 to $5.00 per ton, of alfalfa from $6.00 to $7.00.

BOTTOM LANDS.

These occur generally in great, broad valleys built up by alluvial deposits of which the basic material is of volcanic origin, modified in character and deposition by the action of water, climate and vegetation.

Much of the valley soil is heavy loam or even adobe. There is a general lack of sand and gravel deposits in the entire region, although many of the soils carry a proportion of partially disintegrated rock fragments. These fragments are usually angular and not waterworn and are apparently the result of disintegration of rock *in situ* or with relatively little lateral movement. In this report frequent allusion is made to sandy or gravelly soils or the like. Attention is directed to the use of these terms as implying only that finer or coarser disintegrated rock in greater or lesser proportion is intended by the use of these terms, and not that the sandy or gravelly fragments are waterworn as is usually understood.

As a result of the effects of sorting by gravitation, the steep alluvial fans and foot slopes are built up chiefly of sandy and gravelly loams, of the kind above referred to, while the gentler slopes of the valley lands consist of loams and silty loams. Heavy clay soils occur in the flat basins, except as modified into sandy loam by stream courses. In the swamp areas of Fall River Valley, where little or no sediment is carried by the spring fed streams, extensive peat formations have resulted from vegetation.

Some of the choicest agricultural lands are the verdant meadow areas which have been built up as alluvial fans over the main valley floor. By reason of their slope and the streams which have developed them, they have both excellent drainage and abundant water supply. Such areas are found along Canyon Creek in Warm Springs Valley, Willow Creek in Big Valley and some of the small alluvial areas at the extreme south end of South Fork Valley, and at other places in the basin.

Partially indurated soils or hardpan are found in sections of all of the principal valleys in the basin. While the existence of these hard layers undoubtedly is a detriment to agriculture, it is not as yet fully determined to what extent they may be subdued by deeper tilth or by the continued use of irrigation water. The hardpan is in some local-

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ities clearly indicated by the surface formation, in "hog-wallow the like, or by lack or scantiness of plant growth. In other localit hardpan can only be determined by actual excavation.

The bottom lands are usually irrigated by surface flooding in s as described later. Any surface concentration of alkali is b means washed away in solution. As a general rule little trouble alkali has been experienced in this region. The principal loc where serious injury by alkali has occurred are swampy areas o limited extent.

BENCH LANDS.

These lands are mainly of the type described under the subdi "Plateau Areas" in the chapter on "Run-off." Only a very proportion are capable of tilth, due to the prevalence of scab float rock and to other conditions referred to below. Such li areas as are fairly free from rock usually have soils too shallo too poor in quality to render the land tillable. As a result ther been practically no agricultural development of these plateaus e where certain swampy areas, found therein in natural sinks, have reclaimed by drainage. These swamp areas, either reclaimed or claimed, probably do not exceed 5,000 acres in all. They occur c in and adjacent to Antelope Plains, north of Canby.

South of Pit River, opposite Fall River Valley, is an area of 7,500 acres of agricultural land, mostly of a rolling or broken char This area is partly tilled and dry farmed.

The bench lands west of Hat Creek, in the vicinity of Cassel, ap to be of reasonably satisfactory composition and have been so rep by the soil survey of the U. S. Forest Service. These lands are timb and only one or two isolated tracts are farmed. The principal obs to agriculture will be the removal of stumps and brush.

IRRIGABLE LANDS.

The location of irrigable tracts in the Pit River basin is show Plate 9. Such lands are considered suitable for irrigation and to reasonable prospects of obtaining water, if not already supplied.

Of the gross areas indicated on the map, certain portions are unsu for irrigation by reason of unsatisfactory soil or other condit Other lands have too broken topography or are at too great eleva above possible diversions. With general consideration of these limi conditions an estimate of the net area of irrigable lands in the River basin has been prepared. In this table the figures of the column are inclusive of those of the second column, the latter being areas now under irrigation as described later in detail in the cha on "Present Appropriations and Uses of Water."

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Summary of Irrigable Lands and Portions Now Under Irrigation.

Area	Lands	
	Irrigable	Irrigated
North Fork Valley	2,300	2,300
Jess Valley	4,500	3,400
West Valley	1,200	1,200
South Fork Valley	28,000	19,000
Warm Springs Valley	18,000	4,000
Stone Coal Valley	1,000	500
Ash Creek Valley	5,000	4,000
Round Valley	3,000	1,200
Big Valley	33,000	15,000
Widow Valley	600	600
Little Hot Springs Valley	600	600
Dixie Valley	3,000	1,200
Little Valley	900	900
Pit River bottoms, Big Valley to Fall River Mills	5,000	4,000
Benches south of Pit River, Big Valley to Fall River Mills	5,000	00
Fall River Valley	25,000	6,000
Hat Creek Valley	7,500	3,000
Timbered lands west of Hat Creek extending into Burney Valley	15,000	100
Burney Valley	1,500	1,500
Goose Valley	5,000	3,500
Caton Valley	1,500	1,300
Scattering, on Pit and tributaries below Burney Creek	3,000	2,600
Plateau north of Canby	3,000	500
Miscellaneous small scattering areas not listed in detail	5,000	600
Totals	177,600	77,000

The entire area of the Pit basin is about 4,000,000 acres. Only about 180,000 acres, or less than 5 per cent, are irrigable, and of this irrigable area approximately 40 per cent is under some sort of irrigation. Again, as will be shown later, less than one-half of the area irrigated, or about one-fifth of the entire irrigable area, has an ample water supply. The total acreage which, on account of climate, conditions of water supply and proximity to the range appears to be most naturally adapted for raising wild hay and fall pasturage in connection with the livestock industry, totals some 25,000 to 30,000 acres, or about 15 per cent of the entire irrigable area, including mainly the mountain valleys such as Dixie, Jess and West valleys. The remaining 85 per cent of the irrigable acreage in Pit River basin, amounting to nearly 150,000 acres, is snsceptible of a fairly high grade of development.

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CROPS.

IRRIGATED LANDS.

Wild hay, the natural forage crop of the country, grows in those meadow and bottom lands where an abundant spring and early summer water supply is available. The quality and feeding value of the natural wild hay are largely, if not entirely, dependent on drainage conditions, the better qualities being grown on the better drained lands. On areas with improved drainage conditions, where the water level stands ordinarily several feet below ground surface, timothy, red top or clover are intermixed with the natural hay, the final stand depending on the extent to which one or more of these types may thrive at each particular locality.

Hay lands are irrigated by surface flooding, sometimes called wild flooding. About 2 acre feet per acre appears to be generally used for irrigation in the short season ending about June 20th. After harvest a light irrigation is again applied for pasturage, if a supply is available. Ordinarily temporary dams are placed in the natural stream courses or ditches to facilitate flooding the lands.

A fair crop yield is from three fourths to two tons per acre, with exceptional yield of three tons on small areas of particularly rich land. The average yield is about one to one and one half tons per acre, or about the amount necessary to feed an animal over winter. Under normal conditions hay is considered to be worth $2.00 to $3.00 per ton in the field before cutting. Harvesting and stacking is contracted at $2.00 per ton, making the total cost in the stack $4.00 to $5.00 per ton. Pasturage, after harvesting, is worth about $1.50 per acre, where water for irrigation is available.

Alfalfa is tending to somewhat increase in acreage on account of its greater yield and feeding value, especially for dairying purposes. This crop is generally raised on the better drained lands where the water level stands about 10 feet or more below the ground surface and where the irrigation supply is fairly dependable, its total area under cultivation, however, being quite small.

East of Big Valley Mountain, where the valleys are 4,000 to 4,500 feet elevation, and the growing season 90 to 100 days in length, two crops, with an occasional third crop, are grown. Under present conditions the yield amounts to about 3 tons per acre. After harvest the lands are irrigated for pasturage if water is available. Apparently about 2 acre feet per acre is an adequate supply for this crop, although this is somewhat uncertain.

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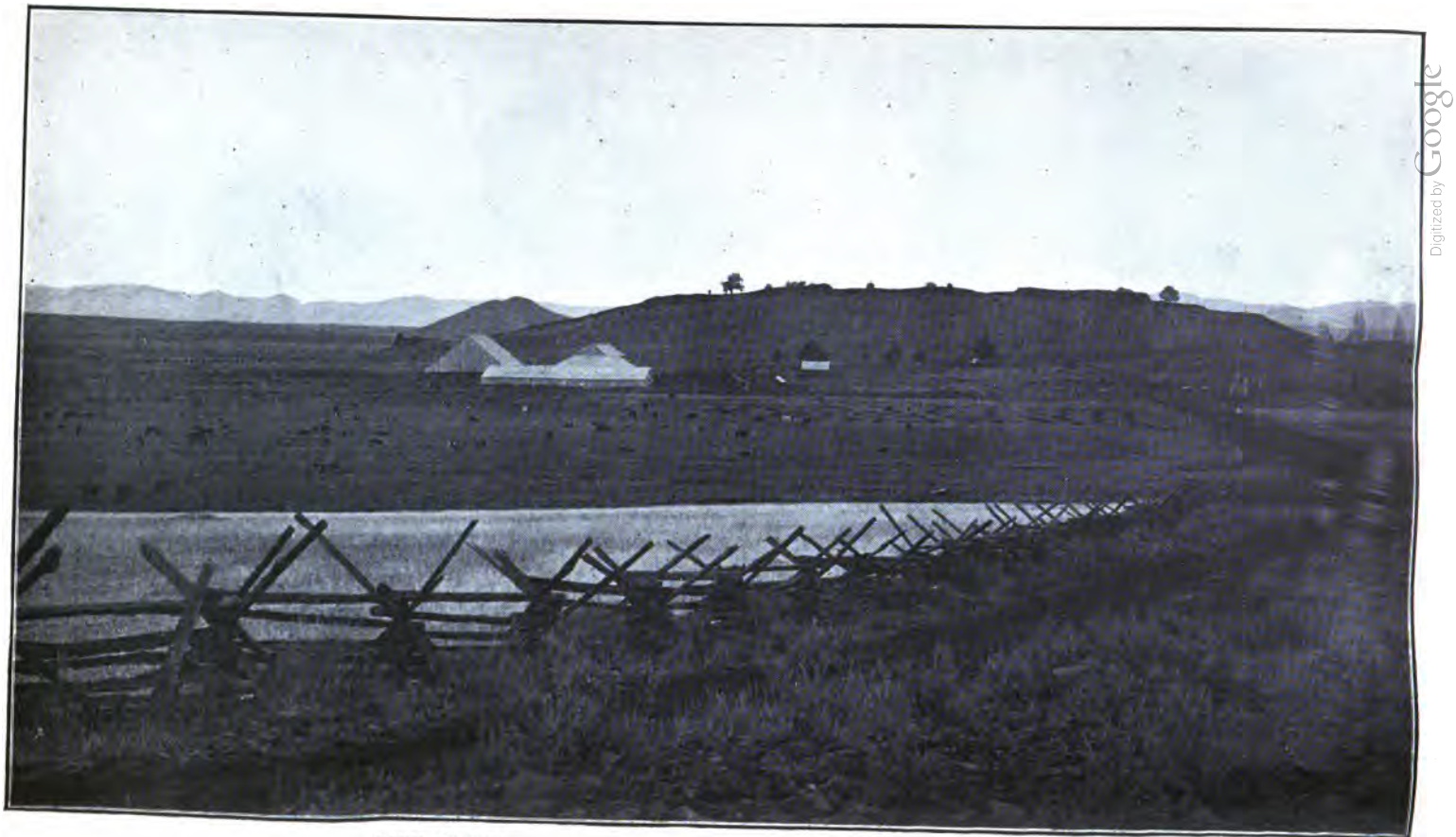

RICH IRRIGATED MEADOW PASTURAGE NORTH FORK VALLEY.

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West of Big Valley Mountain, in Fall River, Hat Creek and Burney valleys, where the valley lands are 1,000 feet lower than those to the east of Big Valley Mountain, the growing season is about six weeks longer, or approximately 140 days, between about the middle of May and the end of September. Three crops, with an occasional fourth crop, are raised. The total yield under present conditions, according to much data furnished by settlers, averages 3½ tons per acre. After harvest irrigation for pasturage is practiced where a supply is available. About 2½ acre feet per acre will give a full season supply.

Alfalfa usually sells at $6.00 to $7.00 per ton in the stack. Harvesting costs about $2.00 per ton. With allowance for labor and irrigation the net returns from this crop amount to about $12.00 per acre for lands east of Big Valley Mountain and about $15.00 for lands west of Big Valley Mountain, or four to five times as much as wild hay. Fall pasturage on alfalfa lands sells at $1.50 or less per acre. The investment in lands and ditches is, however, much greater for alfalfa lands and under present conditions a full season's water supply, necessary for this crop, is not generally available.

A small acreage of grain, probably not over 3,000 acres, is under irrigation, but the character of the lands and conditions are so variable that no information of average returns was obtained.

NON-IRRIGATED LANDS.

Wheat and barley are the staple dry land crops, although some rye is raised. The average yield of wheat appears to be about 15 bushels per acre. The farmer ordinarily receives about one cent per pound for wheat, the gross returns therefore averaging about $9.00 per acre. The cost of producing the crop is about $7.00 per acre, leaving a net profit of about $2.00 per acre. A yield of 20 bushels per acre gives a net return of $5.00 per acre, while 10 bushels, a not infrequent crop yield under unfavorable dry farming conditions, leaves no profit. No extensive areas are devoted to the raising of fruits and vegetables. Weather and soil conditions, and particularly the former, undoubtedly limit quite sharply the areas suitable for such crops, and the variety that may be grown, to a few favorable localities such, possibly, as Little Hot Springs Valley, where an excellent variety of fruits and vegetables, including cantaloupes and tomatoes, is grown freely. Even Jess Valley, at 5,500 feet elevation, possesses gardens producing berries, cauliflower, lettuce and other tender plants.

All hay and alfalfa, and practically all wheat, are consumed in the local market. Hay is used almost entirely in connection with the live-stock industry, while alfalfa is being used to a considerable extent in connection with dairying. Local flour mills convert the grains into flour and other products for local consumption. Conditions of trans-

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portation do not permit the shipping of any but finished farm products of high value such as livestock and cheese, and to a small extent flour and butter, to outside markets.

CONTRIBUTED ARTICLES.

By W. Abbot M. Green of Alturas. That portion of the Pit River drainage area tributary to Big Valley may be roughly described as a plateau region, with an elevation of about 4,000 feet in its lowest parts, and having a slight slope to the southwest. It is broken by numerous mountain ranges reaching the greatest elevation on the eastern border, with intervening valleys. These mountain ranges are, for the most part, of volcanic origin. The valleys show unmistakable evidence of having been at one time mountain lakes and have evidently reached their present condition by the erosion of their outlets, and the filling of the basins with sediment from the adjacent mountains. The result is a series of almost level valleys linked together along the water courses by stretches of more or less precipitous canyons. The tillable land of the area is confined almost entirely to those valleys, the higher lands being chiefly valuable for grazing, though large areas carry valuable stands of timber.

The scant rainfall of the region, coupled with the fact that practically all the precipitation occurs during the winter months, makes irrigation necessary for the most successful farming. The available water supply, however, under the present system of distribution, is wholly inadequate for the irrigation of the entire tillable area, irrigation being now confined mainly to the low lands adjacent to the streams. This leaves the higher lands of the valleys to be farmed, if at all, by dry farming methods.

In dry farming the crops grown are limited mainly to wheat, oats, barley and rye. Many varieties of vegetables can be successfully grown, but such crops are limited by conditions to a sufficient acreage to supply the local demand. In a few instances the growing of small grain, especially rye, has been found profitable for stock feeding, but the use of such forage is limited. The most successful dry farmers are those who practice summer fallowing, with thorough tillage for the conservation of moisture, by which the average yield of wheat is in the neighborhood of twenty bushels per acre. Under the present condition such farming is fairly profitable, but the uncertainty of markets, together with inadequate transportation facilities, makes such farming precarious, to say the least.

Under irrigation all the crops grown by dry farming can be successfully produced, and, in addition, many species of native and introduced grasses and clovers. In actual practice the crops grown under irrigation are confined almost entirely to such as can be used for the winter

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feeding of stock. While the small grains can be successfully grown under irrigation, experience has shown it to be more profitable to devote irrigated lands to the production of hay crops, leaving the production of grain to such land as can not be irrigated. Of the hay crops alfalfa is the most profitable, producing a greater amount of forage, which also possesses a higher feeding value than the grasses. Two crops per year are usually cut, though a third crop is sometimes harvested. The average yield per acre is about three tons of cured hay, though cases are common in which the yield greatly exceeds that amount. The production of alfalfa at the present time is limited to such lands as have good natural drainage. Large areas immediately adjacent to the streams and subject to overflow are too wet, in their natural condition, for the growth of alfalfa, and are devoted to the growing of grasses. Such lands yield from one to two tons of cured hay per acre, the feeding value depending mainly upon drainage conditions. While such hay does not equal alfalfa either in feeding value or yield per acre, it is, and will continue to be, of great importance in stock feeding, owing to the fact that it can be very cheaply grown and cared for. The method of irrigation employed in the production of native hay is usually of the simplest nature, consisting mainly in the flooding of the land during the spring and early summer, which is accomplished by the construction of temporary dams in the water ways. Such a method of course consumes an excessive amount of water, and usually results in the production of an inferior quality of hay, since only the lighter grasses will thrive under excessive flooding. With suitable ditches to divert the water at the proper time so as to keep the land dry during the harvesting period, hay can be produced at a remarkably low cost. Even with the cheap methods of production as practiced, however, the farmer who does not own sufficient stock to consume his entire crop is seriously handicapped. Large quantities of hay are annually sold to be fed on the farms, but in this the producer is usually at the mercy of the feeder. The price paid for hay by feeders usually runs from $4.00 to $6.00 per ton for large quantities, and in many cases this price includes the labor of feeding.

During the past twenty-five years the methods of handling stock have been completely reversed. In the early days of the settlement of the country the vast areas of public range afforded an unlimited supply of summer pasturage, and the stock owner limited his herds to the number he could safely carry through the winter season. Practically all the beef sold at that time went directly from the summer range to market, only stock cattle being fed. The carrying capacity of the ranges has fallen off, due to overstocking and the encroachment of settlers while the production of hay has increased, until at the present time the size of herds is governed by the amount of summer range that can be

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secured, and practically all stock is sent to market from the feed yards during the winter months.

The future development of this country will be mainly along the lines of increased stock production. This will be brought about by bringing large areas of the now dry lands under irrigation by the storage of flood water during the winter season, and the substitution, in part at least, of a rational system of diversified farming in which the only crop sold from the farms will be the finished product from feed yard or dairy for the old time pioneer methods now in vogue.

By H. C. Watson of Bieber (Manager of local cheese factories and creameries). Having been a resident of Big Valley for nearly thirty years, I am interested in its future and venture the following information.

Ten bushels of wheat per acre has been a fair average on dry lands. The irrigation of small grain has not become general because of the expense of getting water under present conditions, even though oats and barley often produce from 50 to 75 bushels per acre where land has a good chance for light sub-irrigation. Dry land alfalfa produces one crop averaging 1¼ tons per acre, and some good pasture, while this land properly irrigated, drained, and leveled, would produce five times the amount. Under the present crude conditions, however, irrigated alfalfa land produces two good crops, and sometimes three, yielding from 2½ to 3 tons per acre annually. Our climate is also well adapted to the cultivation of such vegetables as potatoes, cabbage, turnips, beets, carrots, pumpkins, etc. Under irrigation 150 bushels of potatoes have been produced and other vegetables in proportion.

At the present time dry land is worth from $5.00 to $25.00 per acre depending on location and quality, while irrigated lands are worth as follows: Reclaimed swamp land is worth from $25.00 to $50.00 depending upon the facilities of water control; irrigated bottom land where wild hay is grown with improper drainage, is valued at $25.00 per acre; irrigated alfalfa land is valued at $40.00 to $100.00 per acre.

About the time alfalfa was introduced into our valley the public lands in it were withdrawn by the Government for possible future use as a reservoir, and as a result our people have not been encouraged to prepare their land for alfalfa and make other improvements. Likewise all industries except dairying have been retarded and the population has been greatly diminished.

Grass hay is worth from $4.00 to $5.00 per ton. Alfalfa hay is worth from $6.00 to $7.00 per ton. There is no alfalfa hay for sale as it is all consumed on the dairy ranches on which it is raised. Small grains such as barley, wheat and oats bring on an average of 1 cent per pound. On account of the lack of transportation, the market for grain and hay

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and garden truck is entirely local. There could be a great deal of grain sold to outside markets with proper transportation, but I am of the opinion that it would be much better to encourage the raising of sufficient stock to consume all food stuffs, and return to the land all the barn yard manure. With improved transportation Big Valley could have packing houses, creameries, more cheese factories and a general advancement in agriculture.

Big Valley is practically a stock and dairy section and is well adapted to the raising of full blood stock. Tuberculosis in cattle, and cholera among hogs are rarely known in this section. Under present transportation conditions we receive 2½ cents to 3 cents below San Francisco market quotations for our hogs. This valley produces about 3,000 head of hogs each year.

In 1914 Big Valley produced 215,527 pounds (about 173 tons) of cheese besides sufficient butter to supply local consumption. Like other industries, dairying is greatly handicapped on account of poor transportation conditions. Much of our cheese is damaged on the road, as it is either shipped by stage or by big teams.. It is often three weeks en route to San Francisco. Notwithstanding the damaged condition in which it is delivered to the market, it demands a premium in the San Francisco market. Shipping of butter under present transportation conditions is out of the question.

Dairy cows are worth $75.00 per head, dairy calves six months old are selling at $25.00. The average production annually per cow is $65.00 net to the farmer for milk besides the calf. The demand for small dairy farms is increasing.

But for successful dairying and alfalfa raising we must have irrigation—a system of storage whereby the flood waters can be controlled and used in the time of need. This alone would increase the population and productiveness of our valley five times.

By Wm. Paulk, Farmer, of Bieber, in Big Valley. Regarding crops in this valley under irrigated and dry farming conditions, I have had considerable experience along these lines and find that crops produced by irrigation so far exceed those produced by dry farming methods that the farmer is well repaid for the extra trouble and expense that are naturally created by irrigation systems. As you are well aware, the principal industries of this vicinity are the production of livestock and dairying. It is a natural consequence that the production of hay, grain and root crops engage the most of our attention.

Alfalfa is the principal hay crop and is produced both with and without irrigation. The non-irrigated alfalfa produces two crops per year followed by some pasture in the fall. The irrigated alfalfa produces three crops per year and a very good crop of late pasturage. The yields are 2½ and 5 tons per acre respectively. This crop has a local

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cash market ranging from $5 to $7 per ton. This gives a gross receipt of a possible average of $15.00 per acre from the non-irrigated field and $30.00 per acre from the irrigated lands. The estimated cost of harvesting these crops is $2.00 per ton. This leaves a net return of $10.00 per acre from the non-irrigated and $19.00 per acre from the irrigated lands, allowing $1.00 per acre for water for irrigation.

These same lands under grain cultivation were producing about 20 bushels of wheat to the acre and 30 bushels of barley. This was bringing to the farmer about $12.00 per acre. The estimated cost of producing these crops is $7.00 per acre, leaving the farmer about $5.00 per acre for his profit.

These conditions could no doubt be greatly improved under proper cultivation and the advantage of outside markets that will naturally follow the building of a railroad into this vicinity. The grain crop mentioned above was the average crop grown under dry farming, which is the usual method pursued in this valley. I have known a few pieces of wheat and oats that have been irrigated. There is no record of what the wheat produced per acre but I feel sure that 40 bushels per acre would be a very conservative estimate. The oats produced 110 bushels per acre. Under dry farming methods 40 bushels per acre would have been considered a good yield.

The production of hogs for the outside markets to any considerable extent was begun at such recent date that I can furnish you with no reliable information as to the feeding value of grain and root crops. Beef cattle have never been fed grain in this valley to speak of.

Vegetables, beets and potatoes are grown both with and without irrigation. These productions have a local value only and the price naturally fluctuates so greatly that it is impossible to determine what might be done along this line because of the indifferent cultivation they receive. The present yield is about two to one in favor of irrigation.

The noteworthy fact that nearly all of the wealthy people of this valley are those producing crops under the irrigated systems is a very forceful argument that irrigation is the proper condition for this valley.

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PRESENT APPROPRIATIONS AND USES OF WATER.

GENERAL.

Character of Investigation. This investigation was commenced in the fall of 1914 at a time when irrigation operations in the Pit River Valley had to a large extent ceased. Field work was practically completed during 1914. It has consequently not been possible to obtain first-hand information as to stream flows, quantities of water diverted, water duty and other important details in connection with the uses of water for irrigation during a working season. Dependence has therefore had to be placed on indirect sources of information as to these matters, which have been supplemented by occasional measurements of ditch dimensions and by hearsay evidence. It may therefore result that much of the data herein presented on the present uses of water may err in matters of detail. It is, however, believed that the general results as submitted are substantially correct. Attention is specially directed to the fact that it is not the purpose of this investigation to ascertain precise details in the matter of present uses of water in any one locality, but to learn, in a broad way, the purposes and extent to which water is being used, and if possible to indicate in a similar broad way possibilities of achieving results of greater public advantage than now obtain.

Areas shown in a green tint on Plate 9 are under irrigation of some sort, as described in detail later in this chapter.

Summer Flows Generally Used. Practically all irrigable areas in the Pit River Basin lie east of the mountain divide which extends between the great peaks of Lassen and Shasta. In this region the summer flows of every stream with the exception of Fall River and Hat Creek are now fully used for irrigation. The natural summer yield is, moreover, to a small extent supplemented by a storage supply probably not exceeding 7,000 acre feet per annum in the aggregate.

Pioneer Irrigation Systems and Methods. Irrigation systems are small in extent and crude in construction and operation methods, having been mainly designed and built by individuals or small groups or communities, from time to time, as the needs developed and generally without regard to other consideration than cheapness in first cost. In a number of instances the ditches serve the dual purpose of irrigation and drainage, and as a consequence they are liable to be neither located nor constructed to serve either of these purposes to the best adavntage. They have, however, afforded reasonably economical means of development, and under the circumstances were probably the best adapted to pioneer requirements.

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Use of Water. As a rule water is used lavishly wherever and whenever a supply is available, especially on the bottom lands on which wild hay is raised. Probably an average of about two feet in depth of water is now used in a season in most localities, except where payment is made according to the amount used or where the supply is pumped, a low duty considering the short season during which water is available. East of Big Valley Mountain irrigation for alfalfa extends over about 100 days, while in Fall River and Hat Creek valleys the season is four to five months. Hay lands are generally irrigated until the latter part of June, usually by flooding, with later irrigation for pasturage if a supply is available.

Water Rights. Water rights are based generally on appropriations made under the old state law requiring posting of notice and filing with county recorder supplemented by actual beneficial use, and are considered as attached to the lands on which the water is applied and to pass with such lands when sales are made. No attempt is made herein to report on the nature or extent of existing filings in the county records which for the purposes of this report are unimportant, it being assumed that beneficial use of water on the lands is the only real measure of rights. As detailed later, several companies owning lands in these valleys have constructed ditches having capacities in excess of the needs of their lands, and have sold surplus water to other owners on the basis of payment for quantity delivered. These are the only cases where apparently the ownership of the water and the land rests in different hands, but even in these cases it may be assumed that the water is practically attached to the land.

NORTH FORK VALLEY.

Lands and Crops. South of the divide that separates Goose Lake Basin from the North Fork Valley, and north of the city of Alturas there are about 2,300 acres of lands irrigated under ditches that take out from the North Fork and its tributaries. Irrigation began in 1880. The principal crops are alfalfa, wild hay and grain.

Water Supply. The streams from which supplies are drawn are the main stream of the North Fork and its eastern tributaries—Joseph, Tom, Parker, Swedrengen and Linville creeks, all of which rise in the Warner Range and are perennial. They furnish an ample and dependable water supply until about June 1st, after which the aggregate natural flow probably falls as low as four second feet in an ordinary year. Two small reservoirs, belonging to E. Lauer & Co. of Alturas, have been constructed on the plateau west of the North Fork, to supplement the late summer supply for about 500 acres located two miles northeast of Alturas. These reservoirs are probably capable of yielding a stored supply of about 1,000 acre feet.

Comments. The present water supply is generally adequate for the crops grown.

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JESS VALLEY.

Lands and Crops. This valley is situated about twenty miles southeast of Alturas. About 3,400 acres of the valley floor are irrigated. Wild hay is almost the exclusive crop, and is irrigated in the springtime as copiously as possible and harvested in July. Water is again applied to fields after the July harvest, to improve pasturage.

Water Supply. The ditches take out of Mill, East and Harvey creeks, perennial spring-fed streams rising in the Warner Range and converging into this valley, where they combine into the South Fork of Pit River. Probably an average quantity in excess of two acre feet per acre is used in a season. All operations are on a small scale, the natural stream flow without storage being used.

Comments. For the character and extent of cultivation now being carried on in this valley the water supply is adequate.

WEST VALLEY.

About 1,200 acres of wild hay are irrigated in this valley. The average depth applied in a season probably exceeds two acre feet per acre, this being abundant for the purposes of use and also for pasturage after harvest.

SOUTH FORK VALLEY.

Lands and Crops. About 19,000 acres are under irrigation in the South Fork Valley, extending from a point about three miles east of Likely down to Alturas. The crop is mainly wild hay, but a small proportion is in alfalfa and grain. Wild hay is harvested in July, and thereafter the felds are used for pasturage. Alfalfa and grain are mainly produced in the immediate vicinity of Alturas.

Water Supply. This is from the South Fork of Pit River, Pine Creek (a large feeder from the east), Fitzhugh Creek (a small feeder also from the east), and the North Fork of Pit River. All of these streams head in the Warner Range and are perennial. At the extreme south end of the valley there are some large springs that materially augment the summer supply. South Fork has a minimum discharge of about 25 second feet, a maximum of about 500 second feet, and a mean discharge of about 90 second feet; Pine Creek has a spring discharge of upward of 50 second feet, but in summer it falls to about 5 to 10 second feet; Fitzhugh Creek usually has a discharge of about 10 to 15 second feet in May and early June, and about 2 to 3 second feet in summer. The springs at the south end of the valley flow about 2 second feet.

The cessation of irrigation in West and Jess valleys after the end of June releases for use in the South Fork Valley a considerable proportion of the natural flow previously used in the above mentioned valleys. The return flow and drainage from the irrigated lands in West

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and Jess valleys also aids in maintaining the flow in the South Fork during the summer season. The summer supply is further augmented by storage at Crooks Canyon, on the plateau west of the valley, whence about 1,000 acre feet is obtained.

During an ordinary year it is probable about 35,000 to 40,000 acre feet is available for irrigation use in this valley, by far the greater part of this amount being available in May and June. The amount of water applied probably is about two acre feet per acre, a low duty considering the shortness of the season of application.

Irrigation Works. The floor of the valley has very little gradient, and the natural water courses are inadequate to take care of the spring run-off. Previous to 1900 a large part of the south-central section of the valley was an unreclaimed swamp, although a few small drains had been cut through the lowest portion of it. In 1900 two drainage channels, about 4 feet deep and 30 to 40 feet wide, were cut on each side of the valley, enclosing and reclaiming about 10,000 acres known as the Corporation Ranch. These drainage channels extend northerly from a point about three miles north of Likely for a distance of about ten miles, and serve as outlets for the waters of South Fork and tributaries that had formerly spread over the valley floor and caused the swampy conditions referred to.

About 600 acres unreclaimed swamp remain in the north end of the valley and a small portion of the valley floor is still flooded whenever anything approaching high water occurs in the South Fork or tributaries. This occasional flooding is, however, an entirely different matter from the constantly saturated and useless condition in which the lands were prior to the construction of the channels. The channels not only drain off surplus waters but serve to deliver an irrigation supply during the summer season. Laterals take out from them and distribute over most of the Corporation lands.

Dukes Ditch heads three miles above Likely on the South Fork and delivers water to about 1,500 acres east and west of Likely. It has a capacity of about 15 second feet and a length of about six miles. About one-fourth mile further down stream, on the north side of South Fork, a ditch known as the Corporation or Williams Ditch takes out. This extends six miles north of Likely and irrigates about 1,800 acres. It has a capacity of about 30 second feet. Other local ditches are the Ganstads and the Van Loan ditches, both of which head in the South Fork to the east of Likely.

A ditch owned by the Pitville Ditch and Dam Company of Alturas takes out of the North Fork Pit River about two miles northeast of Alturas, and is used as a supplementary supply for about 1,000 acres adjacent to Alturas on the south and east. The company is not incorporated, and is believed to be practically an association of about six

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settlers. The diversion dam is of timber, about 30 feet in width, with rockfill abutments. The main canal is 12 feet wide at the head, reducing down to about 5 feet at its lower extremity, with a maximum capacity of about 18 cubic feet per second. Each irrigator maintains a portion of the canal.

Comments. In May and early June the water supply is abundant for all lands irrigated in this valley. The supply for the lands served by the Pitville Ditch and Dam Company canal is reported to frequently fail after the early part of June. After about June 15th the supply for lands in the north half of South Fork Valley and those along Pine Creek is liable to fall very low, particularly in July, August and September. The southerly portion of the irrigable area of South Fork Valley, including somewhat more than one half of the entire area and which depends on ditches taking out from the South Fork, has usually an ample supply up to the end of July, after which date there is a deficiency.

Miscellaneous Measurements of Water Flow. The following miscellaneous measurements have been made of various streams and ditches in and tributary to the South Fork Valley (see U. S. Geological Survey Water Supply Report 298):

Date	Stream	Locality	Discharge second feet
Sept. 17, 1904	Ditch—Corporation or Williams	Near Likely (highest ditch on east side)	30
June 7, 1905	Ditch	2 miles east of Likely	23
June 20, 1905	Ditch	2 miles east of Likely	24
Sept. 6, 1905	Ditch	2 miles east of Likely	29
Sept. 17, 1904	Ditch—Dukes	Near Likely (highest ditch on southwest side)	3.3
Sept. 23, 1904	Ditch—Dukes	Near Likely (highest ditch on southwest side	8.7
June 7, 1905	Ditch—Dukes	Near Likely (highest ditch on southwest side)	13.9
June 30, 1905	Ditch—Dukes	Near Likely (highest ditch on southwest side)	9.8
June 8, 1905	Ditch—Ganstads	2 miles east of Likely	6.9
July 2, 1905	Ditch—Ganstads	2 miles east of Likely	8.7
June 8, 1905	Ditch—Van Loan	2 miles east of Likely	35.0
June 20, 1905	Ditch—Van Loan	2 miles east of Likely	25.0
Sept. 15, 1904	Fitzhugh Creek	Near mouth	2.7
July 2, 1905	Fitzhugh Creek	Dotens ranch, 10 miles south of Alturas	1.8
July 25, 1905	Fitzhugh Creek	Dotens ranch, 10 miles south of Alturas	1.4
Sept. 7, 1905	Fitzhugh Creek	Dotens ranch, 10 miles south of Alturas	1.8
Sept. 16, 1905	Fitzhugh Creek	Dotens ranch, 10 miles south of Alturas	2.8
Aug. 26, 1904	Pine Creek	Near Pine Creek post office	7.0
Sept. 5, 1904	Pine Creek	Near Pine Creek post office	22.0
Aug. 11, 1905	Pine Creek	7 miles east of Alturas	12.4
Aug. 22, 1905	Pine Creek	7 miles east of Alturas	11.3

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WARM SPRINGS VALLEY.

Lands and Crops. About 4,000 acres are under irrigation. The irrigated lands extend along Pit River from Alturas to a few miles west of Canby and along tributaries of the Pit, on Rattlesnake and Canyon Creeks and in Black Canyon. Wild hay, alfalfa and grain are the chief crops grown, in that relative order of importance.

Water Supply. The water supply for lands along Pit River is very unsatisfactory, owing to the flashy character of the stream flow. In springtime there is danger of flood damage, in summer the flow generally fails entirely. The maximum recorded flow of the Pit at Canby is 17,000 second feet, while the minimum is 1.5 second feet, though a brief discharge of several thousand second feet is not uncommon when the snows on the plateau melt in spring. Lands along Canyon Creek have a large water supply in May and early June, and in late summer they receive a dependable supply from springs amounting to about four second feet of flow. Rattlesnake Creek is extremely torrential and its discharge fails very early.

Messrs. Thomas and Raker of Alturas own two connecting reservoirs on the plateau northwest of Alturas. The usual storage collected by these reservoirs is about 2,000 acre feet. This supply is carried across the plateau for a distance of about 10 miles in a crudely constructed channel, mainly consisting of connecting natural depressions, supplemented by low dams and embankments, from which seepage losses necessarily are high. The supply is used for the irrigation of about 200 acres of the lands owned by the company northwest of Alturas. Supply not required for these land is sold to settlers near Alturas at $3.50 per miner's inch a season (the miner's inch being considered one-fiftieth part of a second foot). Water is sold on this basis to about 500 acres of outside lands, making the total area irrigated from these reservoirs about 700 acres. This reservoir supply is used for alfalfa, young fruit trees and other crops, and according to statements given, one miner's inch supplies two and one-half acres, equivalent to one second foot to 125 acres, a fairly economical use. The net cost to the settler is thus $1.50 per acre per season.

On the plateau north of Canby three small storage reservoirs, belonging to Messrs. Shippy and Duncan of Canby, furnish a dependable supply for 400 acres of alfalfa and hay land in Black Canyon, four miles north of Canby.

Comments. Lands irrigated along Canyon Creek have a dependable full season supply. Lands in Black Canyon and Warm Springs Valley northwest of Alturas, supplied by storage reservoirs, also apparently have a fairly dependable full season supply. All other lands irrigated, principally along Pit River and Rattlesnake Creek, are inadequately served.

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Miscellaneous Measurements of Water Flow. On September 14, 1904, the flow of Canyon Creek was 3.8 feet. (See U. S. Geological Survey Water Supply Report 298).

STONE COAL VALLEY.

Stone Coal Valley, seven miles southwest of Warm Springs Valley damsite, is the only irrigated area of any size along Pit River between Warm Springs and Big valleys, including about 500 acres of land, principally in wild hay, with fall irrigation for pasturage. The valley is above the level of Pit River. The water supply from Johnson Creek, which enters at the east, is generally abundant in spring, but in summer the flow of this creek and of springs which issue from the base of the mountains totals only from one to three second feet.

ASH CREEK VALLEY.

About 4,000 acres of the floor of Ash Creek Valley, located about 15 miles southeast of Adin, are under irrigation for wild hay. These lands are irrigated after harvest for pasturage. The water supply is obtained from Ash Creek at the south, Cottonwood Creek at the northeast, and numerous large springs. A small storage has been developed on Cottonwood Creek to supplement the summer supply. The supply is abundant to June 1st, but after that date the combined supply falls to from 5 to 15 second-feet, depending on the season.

ROUND VALLEY.

This valley lies directly east of Adin. Twelve hundred acres of the valley floor are irrigated by water in Rush and Ash creeks, both of which are perennial streams. Alfalfa and wild hay are the chief irrigated crops, with late irrigation for pasturage.

The water supply entering this valley is abundant up to June 1st, after which it diminishes rapidly. The summer flow of Ash Creek at the outlet of Round Valley at Adin amounts to from 14 to 25 second feet; the mean flow being about 90 second feet.

Miscellaneous measurements on Ash Creek in Ash Valley and on Rush Creek in Round Valley are as follows (see U. S. Geological Survey Water Supply Paper 298):

Date	Stream	Locality	Discharge, sec. ft.
Apr. 5, 1904	Ash Creek	Ash Valley	194
May 5, 1904	Ash Creek	Ash Valley	189
June 4, 1904	Ash Creek	Ash Valley	30
June 10, 1904	Ash Creek	Ash Valley	27
June 12, 1904	Rush Creek	Round Valley	12
Aug. 30, 1904	Rush Creek	Round Valley	7.6
July 18, 1905	Rush Creek	Round Valley	5.6
Sept. 22, 1905	Rush Creek	Round Valley	5.8

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BIG VALLEY.

Lands and Crops. About 15,000 acres are irrigated in Big Valley, mostly adjacent to courses of the Pit River and its tributaries—Ash, Willow and Butte creeks and Bull Run Slough, all of which traverse the valley floor. Pit River flows from north to south for 20 miles through Big Valley, Ash Creek has a westerly course for ten miles from Adin to the point where it enters Pit River, and Willow and Butte creeks have a northerly course through the easterly part of the valley. About 5,000 acres south of Willow Creek and east of Pit River are irrigated by a canal from Ash Creek. Wild hay and alfalfa, in the order named, are the chief crops irrigated.

Water Supply. The principal sources of water supply are Ash Creek, Willow and Butte creeks (tributaries of Ash Creek), Pit River and Bull Run Slough. This stream flow is supplemented by storage at Roberts Reservoir, two miles above Lookout, where a supply of about 1,000 acre feet is obtained. Of these streams Ash Creek has the largest and most dependable summer flow. Its greatest discharge occurs before irrigation begins and generally falls during May to less than 50 second feet, and during July and August to about 15 to 25 second feet. Willow Creek has a large spring discharge, but in summer falls to about 5 second feet. It is used entirely on adjacent meadow lands for the irrigation of hay and fall pasturage. Pit River has a very large run-off in spring, but fails in summer.

Principal Irrigation Works. While much has been accomplished by the efforts of individual farmers, three organizations—one an incorporated company—have been largely instrumental in the irrigation development so far accomplished. The Lookout Dam Company, an association of four farmers, constructed a diversion dam on the Pit River at Lookout for the irrigation of 1,500 acres along the Pit in that vicinity. In 1884 it took over an old ditch which had been used to operate a grist mill, and built two and one-half miles of main canal by following and improving natural channels much of the distance. Recently a concrete diverting dam has been constructed at Lookout. The main canal is 5 to 10 feet wide and 2 to 5 feet deep, and is claimed to have a capacity of 50 second feet at the head. Irrigation is mainly for wild hay and, after harvest, for pasturage.

In 1884 settlers along Pit River near Bieber organized a voluntary association termed the West Side Irrigation Company, which undertook to perform by cooperative effort certain work, mainly the building of rough timber dams which would raise the water over adjacent lands. About 3,000 acres of hay and alfalfa lands along Pit River in the vicinity of Bieber receives a somewhat haphazard irrigation by this system. Alfalfa is also grown to some extent on the lowlands by subirrigation.

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The C. W. Clark Company, an incorporated company of San Francisco, engaged extensively in the cattle business in Lassen County, has built a ditch about eleven miles long beginning five miles west of Adin and extending thence southwesterly to a point two miles below Bieber. This ditch reclaims about 5,000 acres of swampy land at the mouth of Ash Creek by diverting Ash Creek water therefrom. The water thus diverted is for an irrigation supply for about 5,000 acres of other land owned by this company and others, situated south and east of Bieber. At its head the canal is 3 feet deep and about 15 feet wide. Up to June 20th all the available supply of Ash Creek is usually needed on the reclaimed swamp land referred to, and other meadow lands between Adin and Pit River. After harvest, in the early days of July, the last mentioned lands ordinarily receive little or no irrigation for pasture, but depend on sub-irrigation for that service. The lands lying south and east of Bieber irrigated under the C. W. Clark canal are mostly in alfalfa, their first crop being produced without irrigation. The irrigation supply is available only after June 20th. The C. W. Clark Company is reported to sell its surplus water to settlers at $1.00 per acre for the time water is available.

Comments. The supply in this valley is generally deficient. Meadow and hay lands receive little or no fall irrigation for pasturage and alfalfa lands generally receive irrigation for one crop only. Sub-irrigation is depended on when surface supplies fail.

Miscellaneous Measurements of Water Flow. In addition to measurements on Ash Creek at Adin and on Pit River at Canby and Bieber, the following miscellaneous measurements of the flow of Pit River and Willow Creek have been made (see U. S. Geological Survey Water Supply Paper No. 298):

Date	Stream	Locality	Discharge, sec. ft.
June 13, 1905	Pit River	County bridge east of Lookout	155
July 7, 1905	Pit River	County bridge east of Lookout	57
July 20, 1905	Pit River	County bridge east of Lookout	29
Aug. 19, 1905	Pit River	County bridge east of Lookout	9.9
Aug. 29, 1904	Willow Creek	Near Adin	5.6
Sept. 20, 1904	Willow Creek	Near Adin	5
July 19, 1905	Willow Creek	Near Adin	5.7
Sept. 21, 1905	Willow Creek	Near Adin	4.4

WIDOW VALLEY.

This valley lies about six miles southwest of Lookout in the lower slopes of Big Valley Mountain. It includes about 600 acres of meadow land. The water supply is abundant in spring, but fails in summer.

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LITTLE HOT SPRINGS VALLEY.

This valley is about fifteen miles west of Lookout, and contains about 600 acres of irrigated land. The principal crops are alfalfa and wild hay. Favorable climatic conditions make it possible to raise fruit and vegetables for local markets in neighboring communities. All irrigation is from springs which have a total flow of about 6 second feet.

DIXIE VALLEY.

Dixie Valley lies at the head of Horse Creek, twenty miles southeast of Pitville. About 1,200 acres of the valley are irrigated for wild hay and fall pasturage. The supply is from springs which have a dependable flow of about 12 second feet.

LITTLE VALLEY.

About 900 acres in Little Valley, located below Dixie Valley on Horse Creek, are irrigated by water from Horse Creek for wild hay and fall pasturage. The water supply is ample.

PIT RIVER (Between Big Valley and Fall River Mills).

About 4,000 acres of bottom lands adjacent to Pit River, from the head of the valley five miles above Pitville to Fall River Mills, are under irrigation. Alfalfa and wild hay are the chief crops. For lands above McArthur the supply is obtained from Pit River, Horse Creek, Beaver Creek and small springs. The supply is adequate in spring but deficient in summer. The lands below McArthur are irrigated from Fall River and from small streams and springs from the south. A drainage canal from Fall River Valley supplies water to lands along Pit River near McArthur, water being carried across Pit River in a 16-inch pipe line on the county bridge. At Fall River Mills a ditch delivers water from Fall River to lands on the north side of Pit River, and a 22-inch pipe siphon carries water over the Pit to lands along the south side of the Pit Valley. Lands between McArthur and Fall River Mills always have an ample water supply.

FALL RIVER VALLEY.

Topography. The valley floor includes about 50,000 acres. It is a flat plain tilted in a northerly direction, so that its highest and southerly edge is close to the north bank of the Pit River and its lowest or northerly edge is several miles to the north and about twenty feet lower. The lowest or northerly limit of the plain abuts the Modoc lava flow from which issue the large springs feeding Tule, Lake and Fall Rivers. Pit River lies in a small secondary valley apparently eroded in the southerly edge of the great plain before referred to. The north central half of the valley lies generally at the level of Fall River, averaging from about 1 foot above to about 3 feet below river level, and consists largely of swamp, while the southern half lies 10 to 20

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feet above river level. At the east and west are bench lands 10 to 20 feet higher than the central valley area. As before stated, Fall River with its tributaries, Tule and Lake rivers, rises from springs at the northern edge of the valley and flows with an extremely light grade, averaging about one-fourth foot per mile, toward the south, to within one and one-half miles of the southern edge of this great plain near Fall River Mills, whence it drops to the Pit by two sets of rapids of 19.5 feet and 55 feet fall, respectively, or a total fall of 74.5 feet. On account of the extremely flat grade of Fall River in its course through the main part of the valley and the peculiar topography of the valley, which has an inclination dipping toward the source of the river, it is impracticable to divert a gravity irrigation supply from Fall Rver or its tributaries to any portion of the great plain except such small parts of the swamp as lie below river level.

Lands and Crops. About 6,000 acres are under irrigation in the great plain north of the Pit in Fall River Valley. Of this area, 1,500 acres consist of meadow lands adjacent to Fall and Tule rivers, irrigated only by natural overflow in spring and by sub-irrigation during the remainder of the year. These lands produce hay and abundant pasturage. About 3,500 acres of reclaimed swamp lands, mostly north of McArthur, are mainly in timothy hay. About 1,000 acres, mostly in alfalfa, scattered throughout the plain, are irrigated by pumping.

Principal Irrigation Works. About 6,000 acres of swamp lying north of McArthur have been partly or wholly reclaimed from overflow by means of levees along Tule and Lake rivers. A drainage canal about five miles long has been built through these lands from Tule River to Pit River. This canal, owing to the peculiar topographic formation before referred to, is deeper at its lower than at its upper end, its dimensions being 30 feet wide and 8 feet deep at the upper extremity and 18 feet deep at its lower. This drainage canal is also used for an irrigation supply for the reclaimed swamp, the water being backed up by temporary dams in the ditch and then forced over the land. The canal or drain has a timber headgate at Tule River and a timber chute at its point of discharge into Pit River, near McArthur. This system is proposed for extension to cover a total of about 15,000 acres in all. The main canal serves likewise as a supply canal for the low lands along Pit River, at the east and west of the town of McArthur.

About ten steam irrigation pumping plants are intermittently operated in Fall River Valley. The average lift is 10 to 15 feet. A plant on the Rogers Ranch has operated for 14 years, with a lift of 14 feet from Fall River to lands on the west side. A 12-inch centrifugal pump is driven by a 25-horsepower steam engine. The entire cost of

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the plant is stated by Mr. Rogers to be $1,400.00 f.o.b. San Francisco, or about $1,800.00 installed. This plant is usually operated about fourteen hours a day for an average of forty days each year. About 350 acres of alfalfa and hay land are claimed to be irrigated by this means. The pump discharge measured by the United States Reclamation Service in 1914 was about four second feet when operating at the usual speed. Mr. Rogers says his operation expenses total $8.50 per day, as follows:

2 cords wood delivered at $2.25	$4 50
14 hours labor	3 00
Oils and incidental repairs	1 00
Total	$8 50

Sometimes only one or two crops are produced, although three or four crops can be raised in a full season. Fall pasturage is of high value ($2.00 per acre for September and October), and has been considered by Mr. Rogers more advantageous than late farming. The cost of the plant is thus apparently a little more than $5.00 per acre and the cost of pumping operation about 40 times $8.50, or $340.00—for the 350-acre ranch a cost of about $1.00 per acre. Attention is directed to the fact that this amount is for only forty days' pumping and that it would be more for a full season.

The average amount of water pumped every fourteen hours with pump at normal capacity is $\frac{1}{4}\frac{4}{4} \times 4$ second feet $\times$ 2 acre feet per second foot = 4.8 acre feet. In forty days the supply is 40 = 4.8, or 192 acre feet. The supply per acre is therefore 192 divided by 350, or 0.55 acre feet. As this plant furnishes water ordinarily for one to two crops a year, the average irrigation per crop is 0.55 divided by 1.5, or 0.37 feet, which is about four and one-half inches depth. For three crops the required irrigation would be thirteen and one-half inches, for four crops eighteen inches. While these data are necessarily approximate, it indicates the small amount of water required per acre in Fall River Valley where pumping installations can make deliveries directly to the land without appreciable loss in transmission. A number of farmers are now installing motors and pumps to use electric power from the plant in course of construction at Fall River Mills.

Comments. The water supply available by pumping is far in excess of all needs.

HAT CREEK VALLEY.

From Great Spring to the Pit River about 3,000 acres of land, largely in small detached areas adjacent to Hat Creek, are under irrigation. The principal crops are wild hay and alfalfa, with late irrigation for pasturage. As water is easily diverted from Hat Creek, all ditches

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are local in character. The supply is abundant at all times of the year and is generally used lavishly.

The following measurements of canals and ditches along Hat Creek have been made (see U. S. Geological Survey Water Supply Paper No. 298):

Date	Stream	Locality	Discharge, sec. ft.
Aug. 15, 1911	Canal, irrigation	Diverts from Hat Creek above Hawkins Ranch, near Hat Creek	39.4
May 13, 1911	Ditch, Anderson et al.	At intake, Hat Creek	9.6
May 13, 1911	Ditch, Anderson et al.	At intake, Hat Creek	7.4
May 13, 1911	Ditch, Anderson et al. O. R. L. lateral		2.2
May 13, 1911	Ditch, P. M. Horn	Crossing of Hat Creek Road	3
May 13, 1911	Ditch, H. Morris	300 feet below intake at Hat Creek	12.2
May 13, 1911	Ditch, Olive Updyke	600 feet below intake at Hat Creek	5
May 13, 1911	Ditch, A. M. Reives	900 feet below intake at Hat Creek	12
May 13, 1911	Ditch, L. H. Sullivan	300 feet below intake at Hat Creek	8.3
May 13, 1911	Ditch, H. M. Wilcox	Intake, Hat Creek	49

BURNEY VALLEY.

About 1,500 acres along Burney Creek, above and below Burney, are irrigated. The chief crops are wild hay and alfalfa. The water supply is abundant in spring, after the middle of June the flow of Burney Creek being usually about 15 second feet. The water sinks in the valley below Burney and rises again at Burney Falls, ten miles north.

GOOSE VALLEY.

In Goose Valley, three miles northwest of Burney, about 3,500 acres are irrigated for wild hay. The water supply is from Goose Creek, which has a large discharge in May and early June, but practically fails in summer. The valley is extremely flat and has only recently been reclaimed from swamp. Drainage appears to be the greatest problem, and the ditch system is still being improved. Under present conditions of imperfect drainage it has been difficult to raise satisfactory crops even of wild hay, but with complete drainage there should be no difficulty in this, and the present water supply will probably prove adequate. However, for complete reclamation and the production of the more valuable irrigated crops the supply will be insufficient.

CAYTON VALLEY.

This valley is situated about ten miles northwest of Fall River Mills, About 1,300 acres are irrigated from Cayton and Clark creeks. Wild hay is the chief crop. The water supply is ample.

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PIT RIVER (Burney Creek to Sacramento River).

Along Pit and McCloud rivers and Rock, Nelson, Kosk, Hatchet, Montgomery and Squaw creeks there are a number of small pockets of meadow and garden totaling perhaps about 2,600 acres. The water supplies are obtained locally and are generally abundant.

Bench Land Areas. The only place where an effort is being made to irrigate bench or plateau lands, is at Antelope Plains on the plateau north of Canby. Reclamation of swamps and the impounding of storage is being carried on by Messrs. Leland and Meyers of San Francisco, and about 500 acres is at present under irrigation. Water is obtained from a small storage reservoir to the northeast of the irrigated area. This work was completed in 1914. The entire available area has not yet been placed under irrigation.

Diversion From Cedar Creek to Madeline Plains. During the past four or five years a diverting canal and tunnel have been constructed from Tule Lake (a small lake or marsh on Cedar Creek at the headwaters of the South Fork of Pit River) to Madeline Plains, south of the main divide of the Pit Basin. This work has been carried out by a company that has undertaken the irrigation of several thousands of acres in Madeline Plains. The drainage of about 50 square miles, in addition to what formerly drained into and was lost by evaporation from Tule Lake, has thus been withdrawn from its natural outlet into Pit River basin. The water is impounded by a low dam in Tule Lake, now called Tule Lake Reservoir, located about 12 miles southeast of Likely. It is probable that the total annual supply withdrawn from Pit River basin by this development amounts to about 7,000 acre feet.

Diversion From East Hat and Lost Creeks to Battle Creek. About four years ago the Northern California Power Company constructed a ditch 21 miles long from East Hat and Lost creeks (small feeders of Hat Creek) to Bridge Creek, a tributary of Battle Creek. Battle Creek discharges into the Sacramento oppcsite Cottonwood. The company claims a diversion during the low water season of 600 statute inches, equivalent to 15 second feet. A recent court decision limits the diversion to the time following irrigation uses in Hat Creek Valley.

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SUMMARY OF IRRIGATED AREAS.

Summary of Irrigated Areas.

Locality	Acres
North Fork Pit River	2,800
Jess Valley	3,400
West Valley	1,200
South Fork Pit River	19,000
Warm Springs Valley	4,000
Stone Coal Valley	500
Ash Valley	4,000
Round Valley	1,200
Big Valley	15,000
Widow Valley	600
Little Hot Springs Valley	600
Dixie Valley	1,200
Little Valley	900
Pit River (Pitville to Fall River Mills)	4,000
Fall River Valley	6,000
Hat Creek Valley, including small adjacent areas	3,100
Burney Valley	1,500
Goose Valley	3,500
Cayton Valley	1,300
Pit River (Burney Creek to Sacramento River)	2,600
Bench lands	500
Miscellaneous	600
Total	77,000

The above total includes all lands reported in detail in the preceding pages of this chapter and shown on Plate 9. No attempt is made in this tabulation to differentiate between the character of supplies available in each case.

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POSSIBILITY OF DEVELOPING ADDITIONAL SUPPLIES FROM OUTSIDE OF BASIN.

GENERAL STATEMENT.

Below Big Valley the natural supply from local sources is generally adequate for all local needs, and a supplementary supply is unnecessary or would be more expensive than the development of local supplies. For lands in Big Valley and in the tributary valleys there are possible sources outside of the Pit River basin that will first be considered in detail.

Adjacent drainage areas to the south do not afford any practicable supply; in fact, these areas are more arid than the area of the Pit, and at one point a part of the supply for Pit River is actually being diverted across the divide to water lands in Madeline Plains.

The east side does not offer any promise, owing to lack of supply and to the great and continuous barrier to any diversions offered by the Warner Range.

Along the northwest boundary of the basin there is a possible source of supply from Goose Lake into the upper waters of the North Fork of Pit River and a further possibility of diverting the flow of Willow Creek (an important stream draining a large area north of Pit Basin and west of the Goose Lake Basin) across the northerly divide near Timber Mountain.

WILLOW CREEK.

Description. About 550 square miles of partly timbered, more or less rocky plateau territory, drains into Willow Creek, which enters the Clear Lake reservoir built by the United States Reclamation Service for the Klamath project. Before the construction of the Clear Lake reservoir Willow Creek was the main supply for Lost River, which it entered at a point now submerged in the reservoir. The principal purpose of Clear Lake Reservoir is to restrain the spring floods of Willow Creek and Lost River above Clear Lake dam from passing down Lost River into Tule Lake, a large body of water, a part of the bed of which the Reclamation Service is proposing to reclaim. The plan of reclamation of Tule Lake bottom includes a diversion channel (now built) from Lost River to Klamath River, which when used in conjunction with the Clear Lake reservoir will enable all of the drainage of Willow Creek and Lost River above Clear Lake dam to be diverted into Klamath River, thus relieving Tule Lake of that water.

Another and subsidiary plan of the Reclamation Service is to use a part of the surplus waters of Willow Creek stored in Clear Lake reservoir for irrigation of lands in the Klamath project. Various

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plans are under consideration for such uses, but owing to uncertainty as to the extent of the available supply from Clear Lake and the cost of the works necessary to utilize it, and to other reasons, no definite plan has been adopted.

Supply. The Clear Lake reservoir was first put in service in 1909. A summary of the yearly discharges of Lost River at the dam site prior to the construction of the dam and of Willow Creek at the point where it enters the reservoir since the latter has been built is presented. In addition, a summary is given of annual accumulations or depletions of storage in the reservoir and the losses due to evaporation and seepage.

Table of Data Clear Lake Reservoir.

Year	Yield of Lost River, or Willow Creek, acre feet	Storage in reservoir		Evaporation and seepage losses and uses, acre feet
		Gain, acre feet	Loss, acre feet	
1905	47,000			
1906	153,000			
1907	252,000			
1908	35,000			
1909	108,000	50,000		58,000
1910	137,000	34,000		103,000
1911	178,000	74,000		104,000
1912	80,000		11,000	91,000
1913	89,000	10,000		79,000
1914	221,000	85,000		136,000
Average	130,000			

Method of Diversion Possible. At the southerly extremity of Clear Lake reservoir the rim of the reservoir consists of a low, broad saddle through which a cut is practicable. A canal extending from this point in a direction about due south across the divide of the Pit River Basin near Timber Mountain would deliver into a tributary of the Pit River near Happy Camp, a supply available for use in Big Valley.

A line from the southern extremity of Clear Lake reservoir to the divide of the Pit Basin is only about 15 miles measured as the crow flies, but allowing for unavoidable sinuosities the actual length of a practicable canal would probably be not less than 25 miles from the reservoir to the divide.

Comments. At the present time the reservoir is about one-half full, its capacity being about 450,000 acre feet. The gates at the dam have been closed for six seasons, save that a few thousand acre feet were released each spring to accommodate ranchers in Langell Valley. The average discharge of the stream during the ten-year period on record is 130,000 acre feet per annum. Since the reservoir gates have been closed the aggregate stream discharge into the reservoir has been about 800,000 acre feet, of which possibly 25,000 acre feet have

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been released through the gates and about 240,000 acre feet remained in the reservoir at the end of 1914. Thus about 550,000 acre feet have been lost by evaporation and seepage, or nearly 70 per cent of the inflow from Willow Creek.

It is clearly a matter of doubt as to how much of this supply can be considered as available for irrigation purposes. According to the record there is a gain of only 240,000 acre feet in six years, or about 40,000 acre feet per year, and this during a period when the inflow was about 20,000 acre feet per annum above the normal. If, however, the reservoir had been held at a lower level, with a smaller evaporating surface, the net yield would have been greater.

A very large part of the losses is due to seepage into the reservoir bottom. It is to be expected that these losses will tend to decrease as time goes on and the water-table around the reservoir becomes higher. There is, however, an element of doubt in this, as the territory around the lake is of volcanic formation, known to be extremely porous in some localities and with a water-plane normally at great depth below the surface.

It is, therefore, quite conceivable that the supply from this source will not develop on generous lines, and at the best its determination with any degree of accuracy must rest on a much longer record than is now available.

The average yield of Willow Creek appears to be pretty well established at about 130,000 acre feet per annum. The evaporation of the reservoir will run from 30,000 acre feet to 50,000 acre feet per annum, or an average of 45,000 acre feet, even under most favorable conditions and with the reservoir kept at a low level. The net dependable supply after allowing 10,000 acre feet annually for seepage would apparently not exceed an average of 75,000 acre feet in any event.

Assuming this amount could be released from the south end of the reservoir into a canal leading into the Pit River Basin and that such a canal would have a length of about 25 miles, it is then to be borne in mind that the intervening country through which the canal would pass is the peculiarly porous lava territory referred to in the section on "Porous Lava Areas" in the chapter on "Run-off" of this report. It may, therefore, be further assumed that seepage losses in this canal would be quite serious, unless a large part of the conduit were lined with concrete. Allowing for such measures as could be adopted, short of complete concrete lining, to mitigate seepage losses, it is probable that losses could not be kept down to less than 40 per cent of the water diverted. The net supply that could be received in Big Valley would therefore not exceed $75{,}000 \times 0.6$, or 45,000 acre feet. This figure may be regarded as a maximum, with the likelihood that it could not be

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attained, owing to the various uncertainties referred to. Possibly not to exceed 30,000 acre feet per annum should be taken into serious account.

No estimate of cost of the work is available, but certain approximations have been made indicating that the diversion from the lake would cost about $150,000 and the canal not less than $250,000, or about $500,000 for the water delivered over the Pit River divide, including an allowance of $100,000 for the reservoir. This would be about $17 per acre foot, and might be a possible reasonable solution of the problem if this supply may be properly considered as subject to diversion from the Klamath Basin into the Pit Basin.

Attention is, however, directed to the grave uncertainties involved in this plan, especially in the matter of minimizing seepage losses in the canal. In the absence of satisfactory solutions to all these problems it would be unwise to assume dependence on this supply. However, if we neglect these doubts and assume for purposes of discussion that 30,000 acre feet can be delivered at Big Valley in the summer period when the natural flow of Pit River usually fails, this supply might then be a valuable supplementary supply, enabling the complete irrigation of a large area of valley land.

GOOSE LAKE.

Location and Description. Goose Lake is a large natural lake in northeastern California and southern Oregon, occupying the southerly end of an enclosed basin of 1,100 square miles. The depression constituting the lake bed is thought to have resulted from extensive faulting of the earth's crust along an anticlinal fold.* Along its easterly side the Warner Range, with only a narrow bench intervening, rises sharply to an average elevation of nearly 7,000 feet. To the north and northwest a fairly broad valley extends from the lake toward the mountains which on this side rise with easier slopes to lower elevations. Along the west to southwest boundaries of the basin the formation is of a plateau character with still lower elevations. Along the south side is a gravelly beach at an average elevation of about forty feet above the lake surface. Through the beach formation the old lake outlet has been cut down to an elevation a few feet above the lake surface. The lake itself is about 186 square miles in area, or very nearly one-sixth of the entire drainage area. There is no discharge from the lake through the old outlet except as noted below. Evaporation on the 186 square miles of lake surface and such uses as are made for irrigation on lands marginal to the lake balance the aggregate run-off of the streams and the precipitation on the lake surface.

*Waring, G. A., Water Supply Paper 220, p. 26.

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Goose Lake at some former time must have been an important tributary of Pit River. The high beach at the south end of the lake, and the size of the ancient outlet channel, demonstrate that the lake once stood at a very much higher level and that the overflow must have been of the dimensions of a large river. It is clear that at such times precipitation was very much greater than now. That overflow from the lake continued to some extent until very recent times is indicated by the bare appearance of the outlet channel. In fact, as late as 1868 a small discharge for a few hours is reported by residents to have actually occurred, and in August, 1904, the water lacked only one foot of reaching the outlet. In August, 1914, the lake level was about three feet below the overflow channel.

Quality of Water. The condition of the lake water gives further indication that the lake had a fairly constant discharge through the old outlet at no very remote epoch. While it tastes slightly salty and a pond weed native to brackish waters grows in it, cattle drink it freely and large rainbow trout thrive. The following analysis of a sample of water from Goose Lake was made at the Agricultural Experimental Station at the University of California:

Analysis of Water From South End of Goose Lake.
(Sample taken August 23, 1904, by S. G. Bennett.)

	Grains per gallon	Parts per 100,000
Potassium sulphate (very small)	18.06	30.91
Sodium sulphate		
Sodium chloride (common salt)	7.02	12.02
Sodium carbonate (sal soda)	30.90	52.89
Calcium and magnesium carbonates, etc. (small)	6.99	11.96
Calcium sulphate (gypsum) trace		
Silica (chiefly)		
Organic matter, large, and chemically combined water	3.79	6.48
Totals	66.76	114.26

This result shows that the water is unfit for domestic and irrigation purposes.
(Signed) GEO. E. COLBY.

Lake Elevations, Areas and Capacities. These are given below, all being referred to the water surface of August, 1904, when the lake was sounded and assumed to be 4,800 feet elevation. At that time the water surface was one foot below the old outlet at the south end of the lake. The maximum area of the lake at elevation 4,801 feet, the apparent elevation of the old outlet, is about 61 square miles in Oregon and 125 square miles in California; a total of 186 square miles, or approximately 119,000 acres.

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Areas and Capacities.*

At elevation	Area water surface		Capacity, acre feet
	Square miles	Acres	
Elevation of outlet channel	186	119,000	2,217,000
6 feet below outlet	170	108,000	1,536,000
11 feet below outlet	158	101,000	1,013,000
16 feet below outlet	136	88,300	540,000
21 feet below outlet	85	54,600	183,000
26 feet below outlet	29	18,600	†

*Areas and capacities published in 1912 report of California State Water Commission modified to conform with soundings made by Goose Lake Valley Irrigation Company.
†Practically nothing.

Water Supply. Neither the amount of inflow nor the depth of evaporation loss is definitely known, but the average lake areas, precipitation at nearby places, and records of discharge on some of the streams can be used as a basis for a study and reasonable determination of water supply conditions. The annual replenishment is the sum of the net supply which the watershed around the lake delivers plus the direct precipitation on the lake surface. This is balanced by the average evaporation loss.

The ten-year record of precipitation at Alturas, Cal., which lies sixteen miles south of the lake, averaging 13 inches in depth, should be given most consideration because this station is located in the open valley away from any disturbing topographic influences. A long record at Lakeview, Ore., two miles northeast of the lake, averages 17 inches, but this station is situated at the base of the mountains and consequently receives a relatively greater precipitation. With the records at these stations as a basis, 14 inches has been assumed as the average annual precipitation over Goose Lake.

Local information indicates that probably the mean water level has averaged fully three feet below the outlet channel during the past fifty years, with a corresponding water area of about 112,000 acres, or about 175 square miles. The tributary land drainage has, therefore, been approximately 1,100 minus 175, or 925 square miles. The entire east side and the north and northwest portions of the drainage are mainly well timbered mountains which receive a relatively high precipitation. Records of run-off are available from Drews, Cottonwood, Thomas and Dog creeks, all of which are in Oregon. Fandango, Lassen and Davis creeks are the principal streams that flow into Goose Lake from the Warner Mountains. All of the above streams drain the eastern, northern and northwestern slopes. The conditions of precipitation and run-off in southern and southwestern portions of the drainage area are, however, quite uncertain and no actual measurements of flow exist.

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Metered Stream Flow. A summary of the annual discharge of Cottonwood Creek, near Lakeview, Ore., 1908–1914 (drainage area thirty square miles), is as follows:

Season	Acre feet
1908–09	*26,400
1909–10	25,100
1910–11	29,300
1911–12	22,100
1912–13	15,700
1913–14	27,300
Mean	24,320

*Partly estimated.

The average run-off during this period was slightly below normal. It may be assumed that the average annual discharge of Cottonwood Creek amounts to about 25,000 acre feet, or 833 acre feet per square mile of drainage area.

A summary of all available discharge of Drews Creek near Lakeview, Ore. (drainage area 211 square miles), follows:

Season	Acre feet
1908–09	*105,000
1909–10	89,200
1910–11	81,800
1911–12	41,300
1912–13	47,000
1913–14	91,600
Mean	75,900

*Partly estimated.

It is probable that a longer record of run-off would give a mean run-off of 80,000 acre feet annually, or 380 acre feet per square mile of drainage area for Drews Creek.

The annual discharge of Thomas Creek near Lakeview is as follows. The area of the watershed is about 30 square miles.

Season	Acre feet
1911–12	*12,800
1912–13	10,300
1913–14	18,100
Mean	13,700

*Partly estimated.

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It is assumed that a more probable mean is 14,000 acre feet, or 467 acre feet per square mile for Thomas Creek.

The complete discharge from the metered mountain watershed is as follows:

	Drainage area, square miles	Total discharge, acre feet
Cottonwood Creek	30	25,000
Drews Creek	211	80,000
Thomas Creek	30	14,000
Totals	271	119,000

Average run-off per square mile equals 440 acre feet.

Unmetered Run-off. The additional mountain area of 200 square miles, located largely in the Warner Mountains, averages somewhat higher in elevation and is more productive of run-off per square mile, and for it an average of 500 acre feet per square mile, or 100,000 acre feet total has been assumed. For the valley and bench land area, consisting of 455 square miles, mostly along the north side, a mean run-off of 200 acre feet per square mile, or approximately 90,000 acre feet total is considered a fair assumption.

Summary of Existing Conditions. It is not known how much of the stream flow is disposed of in irrigation uses, evaporation from lands, etc., around the lake, but during recent years it probably has averaged not less than 40,000 acre feet. With this basis, which is necessarily only approximate, the following summary may be accepted as a rough indication of water supply and water usage and loss that have probably existed for the past twenty years.

	Acre feet
Supply from metered streams—	
Cottonwood Creek	25,000
Drews Creek	80,000
Thomas Creek	14,000
Supply from 200 square miles mountains, unmetered	100,000
Supply from 455 square miles valley lands and plateau	90,000
Total gross supply from area around lake	309,000
Deduct for irrigation uses	40,000
Total supply from marginal lands	269,000
Supply from direct precipitation on lake surface, 175 square miles or 112,000 acres multiplied by 14 inches equals	131,000
Total average net supply received annually into Goose Lake	400,000

Of this supply nearly 70 per cent is received from the land areas tributary to the lake, while about 30 per cent is from direct precipita-

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tion on the lake. The total evaporation loss, amounting to 400,000 acre feet over an area of 112,000 acres, indicates that the annual depth of evaporation on the lake is approximately 42 inches, a deduction that apparently is supported by observations made a few years ago at Tule Lake, a body of water of almost equal size but at a somewhat lower elevation and situated about 45 miles due west of Goose Lake.

Probable Changed Condition of Inflow Due to Irrigation. An irrigation project contemplating the watering of a large body of land north and northwest of the lake is now under construction. A reservoir of 60,000 acre feet capacity has been built on Drews Creek (the most important tributary of the lake), and other possibilities of 30,000 acre feet storage on Cottonwood Creek and 35,000 acre feet on other tributaries are under consideration. The company promoting the irrigation development claims to have storage sites of aggregate capacity of 125,000 acre feet, and other known sites may bring the total up to 150,000 acre feet. It is uncertain how much irrigable land around the lake not yet watered exists; it is believed, however, to exceed 100,000 acres in extent. If such an area be irrigated in the next few years it is fair to assume that not less than 130,000 acre feet will be permanently withheld from the lake and that the situation as to lake conditions would be as follows:

	Acre feet	
Supply from streams		309,000
Deduct for irrigation	130,000	
	40,000	
		170,000
Total supply from marginal lands		139,000

An acre of lake surface receives approximately 1.2 feet of rainfall and loses 3.6 feet by evaporation, the net loss being about 2.4 feet per annum. An inflow of 139,000 acre feet will therefore require a water surface of 139,000 divided by 2.4 to dispose of such a supply by evaporation. This will mean the lake would shrink to about 60,000 acres, or one-half its present size. Such a shrinkage would, however, lay bare a marginal area of about 50,000 acres, which in turn would yield a run-off instead of a net loss, as at present. It would be unprofitable to attempt to compute an exact balance between these items, as precise determination is impossible, under the roughly approximate premises alone possible. It is, however, apparent that a lake area of a little less than 70,000 acres would result from the application of the assumptions given above on the irrigation of 100,000 acres of new lands marginal to the lake.

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IRRIGATION WORKS IN NORTH PART OF GOOSE LAKE BASIN.

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lecting consideration of future increase in irrigated marginal it can readily be deduced what will be the net yield of the lake f the lake be lowered to different levels. Under the assumptions ductions that have been made as to the yields of the tributary nd evaporation losses an acre of marginal land is assumed to bout 0.3 acre feet of run-off per annum, and an acre of lake to n a net loss of 2.4 acre feet. If, therefore, the lake surface be d by an acre the net yield of the basin will be increased by 0.3 4 acre feet, for the reason that a net loss of 2.4 acre feet will be d to a net gain of 0.3 acre feet. A reduction of lake area of acres will therefore enable a draft of 27,000 acre feet to be made. llowing table gives the possible annual drafts with the lake main- at different average levels.

Elevation	Acreage of lake	Possible draft, acre feet
----------	119,000	0
below ----------	112,000	0
below ----------	108,000	11,000
below ----------	101,000	32,000
below ----------	88,300	64,000
below ----------	54,600	155,000
below ----------	18,600	252,000

sibility of Diverting a Supply From Goose Lake for the Pit

On Plate 13 is shown a profile of a canal cut through the lake whereby the lake supply could be drawn down upwards of 20 elow its present level. The subgrade of the canal is set at 26 feet present lake level at its upper end, it being assumed that the would operate with a water depth of 8 feet at that point, drawing ke down to 18 feet below its present level. This would enable a of about 150,000 acre feet per annum to be made, reducing the level to less than 55,000 acres. Such a canal would have a length bout 20 miles. The excavation would average 40 feet in depth for miles and would total about 5,500,000 cubic yards. Assuming an age price of 25 cents per cubic yard for earth and $1.00 for rock vation, and assuming further, in the absence of definite knowledge ubsurface conditions, that about one quarter of the excavation will ock, or say an average excavation cost of 50 cents per cubic yard, the total cost of excavation will be $2,750,000. With incidentals, of structures and engineering added, the total will easily read 00,000. The cost of this supply would therefore be about $23 acre foot. There is little probability that these unit prices could ubstantially improved by an adjustment of the canal gradient or h of cut. These figures are submitted to illustrate that from the nomic standpoint any plan involving lowering the lake outlet is not

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desirable. As a matter for practical consideration, however, such a plan has no place. It has been shown that plans for irrigating marginal lands to the lake in Oregon are well advanced in construction and that an ultimate draft of 130,000 acre feet on tributary streams may be expected in the next few years, which will of itself tend to reduce the lake level to about 18 feet below its present elevation. Without attempting to discuss what will be the effect of a lowering of 18 feet of this interstate navigable body of water from the standpoint of legality or of riparian damage, it is clear that a further lowering of the lake for the purpose of watering lands in California would involve interference with rights and priorities already established or well advanced toward establishment, as well as interstate complications.

Acts passed by Congress and by the states of California and Oregon in 1905 and 1906 contemplate the possible lowering of the water level of Goose Lake and the reclamation of a part of the lake bed. At the time the legislation was passed the deepening of the lake outlet by a cut was considered as a practical plan and little irrigation was in contemplation along the marginal lands in Oregon. The studies here made indicate that the lowering of the lake level must be a logical and certain result of the irrigation development in Oregon and that deepening the lake outlet is unnecessary for the purpose of reclaiming the lake bed.

Canal Along Base of Warners to North Fork of Pit River. There is a possible plan of constructing a canal some 35 miles along the east side of Goose Lake, into which the drainage of about 150 square miles of the Warner Mountains might be collected and diverted into the North Fork of Pit River. Such a canal might deliver 20,000 to 50,000 acre feet of unappropriated water annually, depending on the size of canal constructed and whether lined or unlined, at an expense of about $25 per acre foot. As this supply would be mainly obtained during winter and spring, storage on the Pit or elsewhere would add about $10 per acre foot, making the total cost $35 per acre foot. This canal would have the one advantage of providing a supply of water of unquestionable quality, and during summer might be used to some extent for local distribution.

Summary. Any irrigation supply obtained directly from the lake would be of doubtful quality, and its acquisition would be surrounded by legal and practical difficulties of an insuperable character. The only scheme of practicability for using water from Goose Lake basin is by the plan of a diversion or intercepting canal along the base of the Warners supplemented by a reservoir for storage purposes at some point in the Pit basin. This plan at $35 per acre foot is not at all attractive. All things considered, a supply for the Pit basin from this source is infeasible.

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STORAGE POSSIBILITIES IN THE BASIN.

GENERAL STATEMENT.

The drainage basin of the Pit contains a number of valleys admirably shaped for storage purposes, having narrow gorge-like outlets across which dams of moderate size would impound large bodies of water.

The somewhat unusual conditions obtaining in the upper part of this basin are that the available storage capacity is, out of all proportion, in excess of the run-off. Assuming that dams of the heights proposed are practicable (as appears probable), it is possible to impound at the various sites many times the amount of maximum run-off even of the main river.

A dam only 100 feet high at the outlet of Big Valley would create storage of 3,200,000 acre feet, while the maximum discharge on record is only 1,400,000 acre feet in a single year, and the mean discharge is only about 430,000 acre feet per annum. A dam 70 feet high at the outlet of Warm Springs Valley would store 560,000 acre feet, while the average flow of the stream is probably not more than 220,000 acre feet. A 100-foot dam at Round Valley would create storage capacity of 185,000 acre feet, with an average annual stream discharge of probably less than 70,000 acre feet. Again, a 100-foot dam at Jess Valley would give about 245,000 acre feet of storage, for an average discharge of about 50,000 acre feet.

There is yet another large reservoir site at Fall River Mills and McArthur, where a 90-foot dam would impound 650,000 acre feet in Pit and Fall River valleys, which storage could be almost indefinitely increased by moderate increases in the height of the dam.

The problem in this region is not to find storage sites, which are abundant, but to determine the economic extent to which storage can be developed and the best location for each storage. Plate 14 shows the location of all reservoir sites herein discussed.

A report on the Iron Canyon project, issued by the Reclamation Service in November, 1914, deals with the question of storage in the upper Pit Basin for the use and benefit of lands along the Sacramento River below the mouth of the Pit. This report shows that storage on the Pit above Pitville is both unsuitable and uneconomical from the standpoint of usage on Sacramento Valley lands or for flood control purposes on the Sacramento River. It shows, in addition, that storage for irrigation for the benefit of Sacramento Valley lands is feasible at the Fall River Mills site, but less desirable than storage lower down the river.

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The findings of this investigation go to substantiate the conclusions reached in the report on the Iron Canyon project as to the undesirability of Pit River supplies and storage for Sacramento Valley uses. In this report, therefore, no consideration has been given to uses or requirements along the Sacramento River.

It is of the highest importance to bear in mind these limitations, which are further illustrated by the fact that the average annual discharge of the entire Pit River at Big Valley is only 430,000 acre feet, an amount which, if it were possible to wholly conserve and utilize, without any evaporation or other losses, would probably only be sufficient to irrigate about 200,000 acres of land. It is, however, well known that any practical developments of Pit River supplies must necessarily entail heavy losses from evaporation and seepage in the reservoirs and canals, and moreover at times a large part of the flood waters that can not profitably be stored must be wasted. It is, therefore, a physical impossibility to develop a dependable storage supply in the upper valley of more than about one third of the above quantity. During the four year period from 1898 to 1901, inclusive, it is estimated the average yield from Pit River at Big Valley was only about 150,000 acre feet, or not more than enough if fully conserved without losses to irrigate more than about 75,000 acres in addition to present developments, but with such losses as are unavoidable in any system the possible area for development must be very much smaller even than that.

These general figures are submitted to show that the entire supply of Pit River above Pitville practical for utilization is at best scanty and should be used on lands in the Pit River basin, if such are available.

All reservoir sites in Pit River basin which might possibly be used to augment the summer flow available for irrigation are considered here in detail. These sites are Jess and West valleys on the South Fork of Pit River, Round Valley on Ash Creek, Big and Warm Springs valleys on Pit River, and also Dixie and Little valleys on Horse Creek, Widow Valley west of Lookout and Big Springs on Hat Creek. In addition, the possibility of utilizing sites on the plateau in the vicinity of Alturas, including Delta Lake, Crooks Canyon and Big Sage and a succession of very small storage sites along Pit River and other streams where lands are of low agricultural value, are considered.

GENERAL FEATURES OF CONSTRUCTION.

No attempt has been made in this investigation to make borings at the various dam sites or to undertake any elaborate study to determine feasibility of construction at any given point. A careful superficial examination and survey has been made at each point, supplemented occasionally by a few test pits through the surface material. The dams under consideration in this report are of moderate heights and dimensions, and their construction may be reasonably assumed

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as practicable within the estimated costs, unless very exceptional and unfavorable conditions should be disclosed by a final examination.

At all dam sites the formations are of volcanic origin and consist of successive flows of basaltic lava rock, more or less free from tuff and other eruptive materials, or of fairly extensive beds of tuff. At some sites these general formations are both in evidence. The basaltic lava rock is hard and usually weighs 165 to 170 pounds per cubic foot, but the formations are generally very much broken and shattered and, as a consequence, liable to furnish a foundation that is not sufficiently homogeneous to give a uniform bearing, if subjected to large unit pressure, and also one which will permit of considerable leakage.

At some sites, where the flows are of great thickness and fairly massive in character, conditions might be considered favorable for the construction of a masonry dam of moderate height. Two considerations, however, make such dams undesirable. The first objection to a masonry dam is that it lacks elasticity, and is therefore at a disadvantage under conditions likely to arise in this region, where earthquake shocks may be expected, and many of the sites are liable to be located on the axis of fault lines along which movements of the earth's crust are usually most serious. The second objection to such a dam would be the expense of cement. In addition to high railroad charges for freight, a wagon haul of 25 to 50 miles generally over mountain roads is required to reach the dam sites. It is advisable, therefore, to limit the design of dams to types which make maximum use of local materials. Either an earth or rock-fill dam, or a combination of both, meets the requirements of elasticity and minimum expense of transportation.

EARTH DAMS.

Where the formations are mostly tuff, the absence of rock in reasonable quantity prevents consideration of a rock-fill dam. Good earth material is found reasonably near all sites of this character where earth dams are proposed. Their upstream face is designed on a slope of 3 horizontal to 1 vertical, the downstream face 2 horizontal to 1 vertical, with 20-foot crest and the top of dam usually about 10 feet above high water level. Such a dam requires a liberal spillway to carry surplus flood waters from the reservoir without encroaching unduly on the freeboard. A concrete outlet conduit, leading from a concrete gate tower, is used to regulate deliveries of stored water from the reservoir. Riprap facing, 12 to 18 inches thick, is provided for the upstream slope. A very important feature of dams of this kind is the cut-off wall, in cases where one is necessary. This should extend to a sufficient distance under the dam and into the abutments where there is a possibility of dangerous leakage.

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EARTH AND ROCK DAMS.

Where the foundations are of basaltic lava rock an earth and rock-fill dam furnishes a structure which can be constructed of the materials available near each of these sites. The rock-fill is built compactly with upstream slopes of 1¼ horizontal to 1 vertical, and downstream slope of 1½ horizontal to 1 vertical, with top width of about 15 feet. The earth embankment is built as a facing over and against the upstream slope of the rock fill. The upstream slope of the earth facing is designed as 3 horizontal to 1 vertical with 5 feet top width. In this structure the impervious earth facing serves to prevent the escape of leakage while the rock fill withstands whatever pressure may be exerted. The rock fill likewise provides ample and safe drainage for leakage that may escape through or under the earth embankment. As such dams would be constructed on bedrock, generally it would not be necessary to provide for an extensive cut-off wall. All the other features proposed for earth dams, such as a waste-way, gate tower, outlet conduit and riprap facing are likewise needed for the earth and rock-fill dam.

PRICES USED IN ESTIMATES.

The value of all lands that would be submerged has been estimated on a liberal basis. The full market value has been ascertained, so far as possible, from owners or settlers in the locality and others well informed about local land values. In addition, an allowance has been made for the purchase of marginal lands in excess of the areas actually submerged, so as to include odd portions of ranches that would be rendered inaccessible, undesirable or worthless.

Except for team work, which should be low in cost on account of the abundance of cheap hay and grain in this region, construction costs will generally be high. All materials that it is necessary to ship in, such as cement, and all labor and equipment, will be expensive on account of the great distances from the large market and labor centers. On this account it is advisable to make estimates of unit cost sufficiently liberal. In addition, an overhead charge of 25 per cent is added for engineering and contingencies.

JESS VALLEY RESERVOIR SITE.

Location and Description. Jess Valley reservoir site occupies the lower 2,500 acres of Jess Valley, a small mountain-bound valley of the Warner Range 20 miles southeast of Alturas and 12 miles east of Likely. Mill, East and Harvey creeks, small perennial streams of the Warner Mountains, join at the valley outlet, forming the headwaters of the South Fork of Pit River.

A well defined shore line at about elevation 5,200 feet is in evidence around practically the entire site, indicating the existence of a lake at some former era before the valley outlet had been cut down to its

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present stage. The hills rise sharply along the west, while at the east the steep outwash slopes from the mountains extend over the flat valley floor.

Until recently the lower or western part of the valley near the outlet has been swampy, but the excavation of ditches is rapidly converting this swamp into hay land. The rocky washes from the mountains make the eastern portion of the reservoir site suitable for pasturage only. The central part of the basin is meadow land, which produces hay and fall pasturage. Most of the area is in the ownership of one company. About 100 acres of swamp remains in public ownership.

Water Supply. Ninety-one square miles of drainage from the highest portions of the Warner Mountains contribute run-off to the Jess Valley reservoir site. The elevations of the drainage area range from 5,100 feet at Jess Valley to practically 10,000 feet at Eagle Peak, the highest point in the Warners. It is estimated that the annual precipitation over this area varies from 24 to 30 inches, most of which occurs in the form of snow. Much of the run-off is absorbed into the underlying porous formations from which it issues later as springs. As a result the streams that discharge into Jess Valley have a remarkably well regulated flow, and are not subject to large floods in spring or failure in dry years.

From January to September, 1904, inclusive, the estimated discharge of South Fork of Pit River at the Jess Valley damsite was 63,600 acre feet. For the entire year 1904–5 the estimated discharge was 42,800 acre feet. With an approximate record of two years only, the first of which was excessively wet, it is not possible to accurately determine the average annual run-off. However, it is known that in 1904–5 the run-off of the Pit above Bieber was only 70 per cent of normal. As the streams which discharge into Jess Valley are fed by large springs which issue from the porous formations of the Warner Mountains, while much of the drainage tributary to the Pit at Bieber is furnished by flat adobe-capped plateau areas which give a relatively low discharge in years below normal in run-off, it is reasonable to assume that the deficiency in the flow of the Pit at Bieber in 1904-5 was due largely to the plateau areas. It is probable that the run-off of South Fork at Jess Valley in 1904–5 was about 90 per cent of normal. On such a basis the average annual run-off is approximately 42,800 divided by .90, or 48,000 acre feet. On account of underground storage conditions the flow in driest years probably does not fall much below 40,000 acre feet. The extremely large run-off of 1903–4 which would have totaled about 70,000 acre feet for the entire year, may be considered one of maximum discharge which is seldom, if ever, exceeded.

A reconnaissance was made to determine the feasibility of increasing the drainage area by diverting Parsnip Creek, the best stream of West

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Valley, over into Jess Valley. It was found that such a diversion co be made very easily by a ditch only 2,500 feet long where the outlet Blue Lake and springs below the lake join Parsnip Creek on McGarva ranch. In fact, a small ditch had once been constructed al this location to divert water to lands in Jess Valley. The total c struction cost of adding this supply to Jess Valley reservoir wo probably not exceed $2,500, and it is estimated that in the se months of the year during which the flow of this stream is not use total run-off of about 7,000 acre feet would be obtained. This wa supply is very dependable as most of it is from springs.

Of the total average run-off of the South Fork of Pit River from J Valley, thus estimated at 48,000 acre feet, about 15,000 acre feet, pr ably the normal discharge during the irrigation season, is now used South Fork Valley, leaving 33,000 acre feet unappropriated. With 7,000 acre feet available by diversion from Parsnip Creek, the to unappropriated run-off would amount to about 40,000 acre feet. T annual precipitation at the reservoir site is about 24 inches in depth, a the irrigation uses and the water and soil evaporation losses amount fully 36 inches in depth annually. Evaporation and seepage losses o the average water surface of a reservoir should not exceed an ann depth of 40 inches. It seems safe, therefore, to assume that for an av age water surface of about 1,600 acres, which is approximately t present swamp and hay land area, all loss in evaporation and seepa will be offset by precipitation that would be received directly on t water surface and by the water now used for irrigation on the lands the reservoir site. The assumed average water surface is sufficient liberal in area to permit of carrying in reserve a surplus of abo 15,000 acre feet for use in dry years. The net available supply from t reservoir will therefore be estimated at 40,000 acre feet.

Damsites. Along the first 3,000 feet or more at the head of th outlet from Jess Valley there are a number of possible damsites. Nea the upper end the low rounded hills at either side are mostly tuff forma tion and the canyon is free from debris. The width between abutments is from 300 to 500 feet. About a half mile further down the canyon walls rise much higher and the formations are mostly basaltic lava with interbedding of tuff. The debris from the cliffs above has filled the canyon to a V-shaped gorge. On the surface there is a great mass of large angular lava rock underlaid with an aggregate of tuff and smaller rock. In the first 3,000 feet of the outlet from Jess Valley the fall is about eight feet. At these sites the type of dam is limited to either an earth or earth and rock-fill. At the upper site an earth dam appears to be most suitable, as such a structure could be built directly on the alluvial fill, with only shallow stripping. A cut-off probably would be needed to stop percolation under or around the dam. The site likewise

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apparently offers good opportunity for the construction of an outlet tunnel through the south abutment and for a wasteway through a low saddle well back from the dam.

The lower site is not considered favorable, as it would require much expensive excavation to remove the great mass of loose rock talus overlying the site. The expense of building an earth and rock-fill dam or an earth dam would exceed that for an earth dam at the upper site, and wasteway construction would be more difficult.

At the upper site a shallow test pit, sunk to a depth of twelve feet, encountered one foot of soil at the surface, eleven feet of tight blue clay, and water-bearing gravel at the bottom. No attempt was made to go deeper by installing a pump. This test pit gives absolutely no indication of what depth beyond twelve feet bedrock or a tight foundation might be reached, if it should be found at all at this site. It does indicate, however, that there probably would be no great difficulty in stripping enough clay from the area above the damsite for the construction of a low dam.

Reservoir Capacity and Areas. The following table shows the area that would be submerged and the storage for various heights of the water line above the level of the average ground surface at the dam. The corresponding elevations, assumed datum, of the water level are also given.

Height of water level above plain at dam	Elevation water surface, assumed datum	Area flooded, acres	Storage, acre feet
0 feet	100	0	0
2 feet	110	810	810
12 feet	120	1,730	13,500
22 feet	130	2,160	33,000
32 feet	140	2,460	56,000
42 feet	150	2,700	81,000
52 feet	160	2,880	110,000

NOTE.—The ground surface at the damsite averages about 108 feet elevation, assumed datum.

Construction Details. As it is proposed to carry a surplus of 15,000 acre feet in addition to the annual supply of 40,000 acre feet, storage should be provided for fully 55,000 acre feet. It will be assumed that the storage level would be 140 feet elevation, assumed datum, or 32 feet above the base of the dam. The height of the dam would be 42 feet, or 150 feet elevation, assumed datum. In the absence of definite information about the foundations, it is assumed that it will be necessary to carry a well-timbered trench to an average depth of 40 feet and to refill this trench with clay puddle. The probability of encountering a large volume of water in this excavation

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would make the unit cost high. North of the Flernoy ranch house, one mile east, a pit of excellent wash gravel, which has been opened up for surfacing of roads, would be very suitable for use in concrete.

Such equipment, materials and supplies as it would be necessary to ship for this work could be delivered at Likely, twelve miles west, on the N. C. O. Railway. The haul by team would be about fifteen miles.

Estimates of Cost.

Stripping 2,000 cubic yards at 25 cents	$500	
Excavation of cut-off—		
Bottom, 5,000 cubic yards at $3	15,000	
Sides, 2,000 cubic yards at $1	2,000	
Clay puddle, 7,000 cubic yards at $1	7,000	
Earth embankment, 72,000 cubic yards at 50 cents	36,000	
Riprap, 1 foot thick, 2,000 cubic yards at $3	6,000	
Outlet tunnel, lined, 250 cubic feet per second capacity, 400 feet at $25	10,000	
Gate tower and gates	6,000	
Wasteway, 2,500 cubic feet per second capacity—		
Excavation, 10,000 cubic yards at 75 cents	7,500	
Concrete, 600 cubic yards at $12.50	7,500	
Road construction	1,000	
Diversion canal from Parsnip Creek	2,500	
Total cost of construction	$100,000	
Engineering and contingencies at 25 per cent	25,000	
Total		$125,000
Land and damages, including overhead expense—2,460 acres submerged; 3,200 acres purchased—		
2,000 acres of hay land and improvements at $30	$60,000	
1,200 acres pasture at $15	18,000	
Miscellaneous damages	5,000	
Total lands and damages		$83,000
Total cost of storage		$208,000

On the basis of 40,000 acre feet net annual supply, the cost of storage would be $5.20 per acre foot.

WEST VALLEY RESERVOIR SITE.

In 1904–05 the run-off past the West Valley reservoir site was 17,100 acre feet. The normal annual run-off probably amounts to 19,000 acre feet, as 1904–05 was about 10 per cent below normal for streams tributary to the upper Pit which are fed largely by springs. Recently Tule Marsh has been converted into a reservoir and additional drainage from some 50 square miles on upper Cedar Creek diverted into it. This water is carried to Madeline Plains, where it is used for irrigation of lands in the vicinity of Madeline. It is probable this development has withdrawn about 7,000 acre feet from the drainage tributary to West Valley.

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A storage development of 12,000 to 15,000 acre feet in West Valley, where the land values destroyed and the construction costs would be comparable with those of Jess Valley, making the unit cost of storage fully three times as high, would certainly not be practicable. It is better to divert upper Parsnip Creek, a tributary of West Valley Creek, into Jess Valley Reservoir, and make that development as favorable as possible.

WARM SPRINGS VALLEY RESERVOIR SITE.

Location and Description. The Warm Springs Valley Reservoir site is located west of Alturas below the junction of North and South forks of Pit River. The small settlement of Canby is located at the north side of this site. The area that would be submerged by storage consists mostly of a long narrow strip of hay and grain land adjacent to Pit River extending some 10 to 20 miles in length, depending on how large a storage might be developed. The hill slopes at either side of the valley are now used for pasture or dry farming. The average elevation of this reservoir site is about 4,400 feet. The valley area is generally poorly developed agriculturally on account of unsatisfactory water supply conditions.

In 1904 a topographic survey of the reservoir site was made by the United States Reclamation Service. The following table shows the areas that would be flooded and the storage secured at various levels above the stream bed at the damsite:

Height of water level	Area flooded (acres)	Storage capacity (acre-feet)
0 feet	0	0
10 feet	78	261
20 feet	641	3,860
30 feet	2,920	21,700
40 feet	7,470	73,700
50 feet	13,000	176,000
60 feet	19,400	338,000
70 feet	24,700	559,000

Water Supply. The drainage area tributary to this site includes about 1,500 square miles, about one-fourth of which comprises a portion of the westerly slope of the Warner Range and the mountains south of Canby. These mountain areas, ranging from 6,000 to 10,000 feet in elevation, receive a precipitation of 18 to 30 inches. Their run-off is of a very dependable character, as the streams are mainly fed by springs which issue from large underground storage. Little of the discharge from these mountain streams, however, reaches Pit River at Canby during late spring or summer, as practically the entire flow at such times is used for irrigation on lands higher up on the Pit and its

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tributaries. The other part of the drainage area, consisting of valley and plateau, lies at elevations from 4,300 to 6,000 feet, and probably the annual precipitation on these areas is not more than 13 to 18 inches. The run-off ordinarily is relatively small and not dependable, while in dry years it is liable to fail completely.

Records of run-off on Pit River near Canby were made during 1904–05, a period too short to indicate directly the mean discharge of this flashy stream. By comparing this record with that of the Pit below Bieber, where a gaging station was maintained for a longer time, and where a reasonable relationship with the annual discharge on the Sacramento at Red Bluff has been established, by analogy a similar estimate or assumption of discharge at Canby for a long period can also be made. A comparison of the flows on the Pit at Canby and at Bieber during the only period of actual measured record is as follows:

Run-off in Acre Feet.

	Pit at Canby (1)	Pit at Bieber (2)	Ratio of flow (1 to 2)
1904—January to September	665,000	1,210,000	55%
1904–05	165,000	303,000	54%
1905—October to December	15,600	29,300	53%
Entire period	846,000	1,540,000	55%

The close agreement of the relative discharge at these two stations for these two years, the first of which furnished an excessive run-off and the second about 70 per cent of normal, although probably largely accidental, does to some degree justify the only conclusion possible on the data at hand, viz, that the flow of the Pit at Canby probably is about one-half of that at Bieber. Likewise the drainage area above Canby is approximately one-half that above Bieber.

It has been determined that the annual discharge of the Pit at Bieber varies from 2.4 to 8.8 per cent of that of the Sacramento at Red Bluff, the lower percentage corresponding with years of low run-off on the Sacramento. Such a relationship seems reasonable, for the great flat plateau area tributary to the upper Pit has a very great variation in run-off in wet and dry years, while the large perennial spring-fed streams which begin with Fall River and end with the McCloud contribute an extremely well sustained flow at all times to the Sacramento.

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The following tabulation shows the probable run-off on the Pit at Canby during the past 19 years:

	Estimated run-off, Pit at Bieber, in acre feet	Estimated run-off, Pit at Canby, in acre feet
1895–96	[1]470,000	[1]258,000
1896–97	[1]404,000	[1]222,000
1897–98	[1]60,000	[1]33,000
1898–99	[1]87,000	[1]48,000
1899–1900	[1]213,000	[1]117,000
1900–01	[1]239,000	[1]131,000
1901–02	[1]497,000	[1]273,000
1902–03	[1]302,000	[1]166,000
1903–04	[2]1,400,000	[2]770,000
1904–05	[3]303,000	[3]165,000
1905–06	[3]755,000	[1]415,000
1906–07	[3]1,110,000	[1]610,000
1907–08	[3]187,000	[1]103,000
1908–09	[1]858,000	[1]472,000
1909–10	[1]241,000	[1]133,000
1910–11	[1]337,000	[1]185,000
1911–12	[1]102,000	[1]56,000
1912–13	[1]103,000	[1]57,000
1913–14	[4]617,000	[1]340,000
Average for 19 years	436,000	240,000

NOTE.—In compiling the above table advantage has been taken of additional data available since the publication of the Iron Canyon project report of 1914.
[1]Estimated.
[2]Partly estimated.
[3]Actual record.
[4]Mostly actual record.

Should Warm Springs Valley be used as a reservoir site there probably would be not more than 25,000 to 30,000 acre feet of storage developed for lands above. With allowance for return waters the net reduction in run-off would be about 20,000 acre feet. In addition, at least 5,000 acre feet of the stream flow is now used in Big Valley above and below Lookout for irrigation in early spring. It would, therefore, probably be safe to use this nineteen-year record of discharge of the Pit at Canby as a basis for determining the supplies available for storage, only after having reduced the gross run-off of each year to the extent of 25,000 acre feet.

In examining the nineteen-year record it will be observed that there were two dry periods of two years each when it would have been necessary to draw on the storage previously accumulated to provide for a net water supply of 45,000 to 50,000 acre feet, the amount which

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may be obtained from Round Valley. Considering these two dry periods and the year preceding each we have:

	Gross run-off on Pit at Canby	Reduction due to other appropriations	Net run-off available for storage
1896–97	222,000	25,000	197,000
1897–98	33,000	25,000	8,000
1898–99	48,000	25,000	23,000
Totals	303,000	75,000	228,000
Average	101,000	25,000	76,000
1910–11	185,000	25,000	160,000
1911–12	56,000	25,000	31,000
1912–13	57,000	25,000	32,000
Totals	298,000	75,000	233,000
Average	96,000	25,000	77,700

Under conditions of the first dry period of 1897–99 it would be possible to obtain a net annual yield of 45,000 acre feet by using the surplus from 1896–97. The average water surface would be about 8,000 acres in area, and with an annual evaporation and seepage loss amounting to about 3.75 feet depth annually over the water surface, approximately 90,000 acre feet, or over one-third of the entire water supply, would be lost in evaporation and seepage. The maximum area flooded, at the beginning of the irrigation season of 1896–97, would be 12,000 acres. For the second dry period of 1911–13 a net annual yield of 50,000 acre feet could be obtained by holding all surplus storage from 1910–11. The average area flooded would be 7,000 acres, the maximum 11,500 acres. In this case about 80,000 acre feet, or over one-third of the total water supply would be lost in evaporation and seepage. It appears, therefore, that to secure a safe net annual yield of 45,000 to 50,000 acre feet it will be necessary to provide a storage of about 150,000 acre feet, flooding 12,000 acres of land.

By providing a larger storage capacity and flooding a larger area, carrying over storage from two or three preceding years, a greater yield can be obtained. The available supply of the four years 1895–96 to 1898–99 is as follows:

	Gross run-off	Reduction due to other appropriations	Net run-off available for storage
1895–96	258,000	25,000	233,000
1896–97	222,000	25,000	197,000
1897–98	33,000	25,000	8,000
1898–99	48,000	25,000	23,000
Totals	551,000	100,000	461,000
Average	138,000	25,000	115,000

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An average water surface of 11,500 acres would dispose of about 172,000 acre feet, or over one-third of the total supply and the safe annual yield would be about 70,000 acre feet. For such a storage a basin of 300,000 acre feet flooding 18,000 acres would be required.

Assuming, as a favorable condition, that at the beginning of the irrigation season of 1894–95, 300,000 acre feet of a full storage capacity of 350,000 acre feet remained on hand, the supplies available would be:

Storage at beginning of irrigation season run-off	Acre feet
1894–95	300,000
1895–96	233,000
1896–97	197,000
1897–98	8,000
1898–99	23,000
Total	761,000

Fully one-third of this supply would be lost in evaporation and seepage from an average water area of 15,000 to 16,000 acres, leaving only about 500,000 acre feet, or an annual net yield of 100,000 acre feet available for use. The maximum area flooded would be 20,000 acres.

That the conditions depicted for the above period are not unusually severe may be shown by an analysis of the period of 1908–09 to 1912–13 in which the supplies available were as follows:

	Run-off, acre feet	Run-off less 25,000 acre feet appropriated, acre feet
1908–09	472,000	447,000
1909–10	133,000	103,000
1910–11	185,000	160,000
1911–12	56,000	31,000
1912–13	57,000	32,000
Totals	903,000	778,000
Average	181,000	156,000

In this period an average evaporating surface of 16,000 acres would have disposed of 275,000 acre feet, or over one-third of the total available storage, leaving a total of 500,000 or 100,000 acre feet per year. The maximum area flooded would be 21,000 acres and a storage capacity of 400,000 acre feet would be required. The conditions of this period are, therefore, even more severe than in 1894 to 1899.

While it is probable that by carrying over storage for six to eight years a yield slightly in excess of 100,000 acre feet, possibly as much as 125,000 acre feet, might be developed by submerging a much greater

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area, such a scheme would be entirely impractical. Any storage materially in excess of 400,000 acre feet would interfere seriously with drainage from South Fork and North Fork valleys, and might even require a flooding of Alturas. As it is quite evident that the cost of any storage in Warm Springs Valley is prohibitive on account of the value of the lands that would be flooded, it appears unnecessary to consider a development above 100,000, which would introduce additional serious complications. The storage possibilities may be summarized as follows:

	Acre-feet	Total storage capacity required, acre feet	Area submerged, acres
Safe annual yield	45,000	150,000	12,000
Safe annual yield	70,000	300,000	18,000
Safe annual yield	100,000	400,000	21,000

While the above analysis is at best but a rough approximation it indicates clearly what great losses would occur in evaporation and seepage and the large areas that it would be necessary to submerge in securing a safe annual supply of 45,000 to 100,000 acre feet.

Damsite. The Warm Springs Valley damsite is located about four miles southwest of Canby. At this place the Pit flows through a narrow gorge about 200 feet wide. The hills at either side consist of well exposed massive basaltic lava rock, and as this formation extends to the edge of the river bottom at both sides there seems every probability that bedrock would be found at a depth not exceeding 20 feet. The site would probably be suitable for a masonry dam, but the transportation of cement by rail and team would probably make such a structure prohibitive in cost.

Construction Details. A quarry can be opened at the site. All rock excavated for a wasteway channel could be used in the rock fill. Earth can be obtained for the earth facing with one-half mile haul. At several places in Warm Springs Valley good wash gravel suitable for concrete is found.

Such equipment, supplies, etc., which would be shipped could be delivered at Alturas, a station on the Northern California and Oregon Railway about 25 miles to the east. There is a fairly good road free from heavy grades from Alturas to the damsite.

Estimates of Cost.

These are given for reservoirs of three different capacities, as follows:

Net annual yield	45,000 acre feet.
Storage capacity	150,000 acre feet.
Area submerged	12,000 acres.
Area necessary to purchase	16,000 acres.
Height of dam	60 feet.
Depth of water at dam	48 feet.

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Excavation—		
Wet, 40,000 cubic yards at $1.50	$60,000	
Dry, 10,000 cubic yards at $1.00	10,000	
Embankment—		
Rock fill, 48,000 cubic yards at $1.50	72,000	
Earth, 35,000 cubic yards at 60 cents	18,000	
Riprap, 2,500 cubic yards at $3.00	7,500	
Outlet conduit, 230 linear feet at $20.00	4,600	
Gate tower and gates	5,000	
Miscellaneous, bridge and road	7,500	
Total cost of construction	$184,600	
Engineering and contingencies at 25 per cent	46,150	
Total		$230,750
Lands and damages—		
3,000 acres at $40	$120,000	
7,000 acres at $30	210,000	
6,000 acres at $15	90,000	
Damages	10,000	
		$430,000
Total		$660,750

For 45,000 acre feet net annual supply the cost per acre foot of storage is $14.67.

Net annual yield	70,000	acre feet.
Storage capacity	300,000	acre feet.
Area submerged	18,000	acres.
Area necessary to purchase	25,000	acres.
Height of dam	70	feet.
Depth of water at dam	58	feet.

Excavations—		
Wet, 46,000 cubic yards at $1.50	$69,000	
Dry, 12,000 cubic yards at $1.00	12,000	
Embankment—		
Rock fill, 80,000 cubic yards at $1.50	120,000	
Earth, 50,000 cubic yards at 60 cents	30,000	
Riprap, 4,500 cubic yards at $3	13,500	
Outlet conduit, 300 feet at $20	6,000	
Gate tower and gates	7,500	
Miscellaneous, bridges and road	7,000	
Total cost of construction	$266,000	
Engineering and contingencies at 25 per cent	66,500	
Total		$332,500
Lands and damages—		
5,000 acres bottom land at $40	$200,000	
10,000 acres grain land at $30	300,000	
10,000 acres pasture land at $15	150,000	
Miscellaneous damages	15,000	
		665,000
Total		$997,500

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For 70,000 acre feet net annual supply the cost per acre foot is $14.25.

Net annual yield	100,000	acre feet.
Storage capacity	400,000	acre feet.
Area submerged	21,000	acres.
Area necessary to purchase	28,000	acres.
Height of dam	75	feet.
Depth of water at dam	63	feet.
Excavation—		
Wet, 50,000 cubic yards at $1.50	$75,000	
Dry, 13,000 cubic yards at $1	13,000	
Embankment—		
Rock fill, 100,000 cubic yards at $1.50	150,000	
Earth, 70,000 cubic yards at 60 cents	42,000	
Rip-rap, 6,000 cubic yards at $3	18,000	
Outlet conduit, 325 feet at $20	75,000	
Gate tower and gates	10,000	
Miscellaneous, bridge and road	7,500	
Total cost of construction	$390,500	
Engineering and contingencies at 25 per cent	97,600	
Total		$488,100
Lands and damages—		
5,500 acres bottom land at $40	$220,000	
10,500 acres grain land at $30	315,000	
17,000 acres pasture land at $15	255,000	
Miscellaneous damages	25,000	
		$815,000
Total		$1,303,100

On the basis of 100,000 acre feet net annual supply the cost per acre foot would be about $13.03.

ROUND VALLEY RESERVOIR SITE.

Location and Description. The Round Valley Reservoir Site is on Ash Creek, below Rush Creek, a tributary which enters from the northeast. The town of Adin, at the eastern edge of Big Valley, is less than one-half mile below the damsite.

The average elevation of this reservoir site is 4,200 feet. It consists of about 2,700 acres of grain, meadow and pasture land. Practically the entire area is in private ownership. A topographic survey of this reservoir site was made by the United States Reclamation Service in 1904, showing the areas that would be flooded and the storage that

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would be impounded at various heights above the stream channel at the damsite as follows:

Height of water level	Area in acres	Total capacity in acre feet
0 feet	0	0
10 feet	65	218
20 feet	304	2,060
30 feet	528	6,220
40 feet	918	13,500
50 feet	1,430	25,200
60 feet	2,060	42,700
70 feet	2,860	67,300
80 feet	3,560	99,400

Water Supply. The drainage area is 265 square miles, ranging from 4,300 feet to 7,100 feet in elevation, over which annual precipitation is about 14 to 24 inches.

In the portion of 1904 from March 13th to September 30th the total estimated run-off was 102,000 acre feet, as compared with 55,600 for the entire year 1904–1905. The relative fluctuation is much greater than on the head of the South Fork at Jess Valley, and at the same time very much less than on the Pit at Bieber for the same period. The flow on these streams was as follows:

	March 13 to September 30, 1904 (1)	1904-05 (2)	Ratio (1) to (2)
Pit at Bieber	839,000	303,000	1 to 2.8
South Fork Pit at Jess Valley	55,000	42,800	1 to 1.3
Ash Creek at Adin	102,000	55,600	1 to 1.8

The flow of the Pit at Bieber was probably 30 per cent below normal in 1904–1905; that on South Fork of Pit at Jess Valley was about 10 per cent below normal. By analogy it has been deduced that the run-off of Ash Creek in 1904–1905 would be about 15 per cent below normal, the latter therefore being about 65,000 acre feet. All indications point to the probability that yields of less than 50,000 acre feet may be expected in years of drouth.

The seasonal period of greatest discharge in Ash Creek is from February to May, preceding almost entirely the full irrigation season, consequently only a relatively small portion of the run-off is utilized under present conditions. In the season of 1904–1905 there was less than 10,000 acre feet discharge from May to September, inclusive, and it is safe to assume that this amount fully covers all appropriations for irrigation, leaving 55,000 acre feet run-off available for storage.

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With a surplus storage of about 12,000 acre feet held in reserve for a single dry year, the average water surface would be about 2,000 acres. Evaporation and seepage losses of four feet annual depth would reduce the gross storage 8,000 acre feet, leaving 47,000 acre feet available for use, or enough to irrigate 23,500 acres of land on a basis of two acre feet per acre.

Damsite. The damsite is at the west side of Round Valley at the outlet gorge through which Ash Creek flows into Big Valley. This gorge is only 200 feet in width at the damsite. The hills are well rounded with a capping of basaltic lava, especially at the southwest. It is concluded on the basis of numerous exposed sections of the rock formation that these basaltic lava flows are in very thin sheets, at places not over a foot or two in thickness, and that the underlying formation is mostly tuff.

At the center of the damsite a test pit was sunk to a depth of 15 feet through impervious blue and yellow clay. Under the clay coarse gravel was found, and the very free flow of water from this formation prevented further progress of excavation without pumping, which was not attempted. There is, therefore, no information as to the depth bedrock or other satisfactory foundation might be found at this site, nor what the character of the foundations may be. The general configuration of the abutting hills and the narrow gorge have led to the conclusion that bedrock lies at moderate depth, perhaps not more than 20 to 30 feet below the surface. In view of the fact that lava rock appears to be superficial and apparently is invariably underlaid by tuff, particularly at the abutments, there is every prospect that the "bedrock" at this site is tuff.

Construction Details. An earth dam seems to be the most practicable structure for this site on account of the scarcity of other material. An ample amount of good embankment earth can be obtained in the valley floor above the damsite. In the absence of definite information as to substratum it is assumed that a satisfactory cut-off wall could be secured at an average depth not exceeding 50 feet below the ground surface. A concrete gate tower and outlet conduct of 300 second feet capacity, and a masonry lined wasteway capable of delivering a flow possibly as large as 10,000 second feet should be provided. As it is proposed to provide storage for 67,000 acre feet a dam 80 feet high would be required. The yardage in the embankment is sufficiently large to warrant an estimate of 50 cents per cubic yard for earth fill as used at Jess Valley. An upstream slope of 3 horizontal to 1 vertical, downstream slope of 2 horizontal to 1 vertical and top width of 20 feet is proposed, with the top of dam 10 feet above high water. The upstream slope of the dam would require a riprap facing about 15

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inches in thickness. Gravel for concrete can be obtained from Butte Creek, one mile south of Adin, with a haul of 1½ miles.

All equipment and materials shipped in would probably be delivered from Madeline, on the Nevada-California-Oregon Railroad, 35 miles southeast of Adin, although with an improved road over Big Valley Mountain freight might be delivered cheaper from Bartle, the terminus of the McCloud River Railway, 70 miles west of Adin. The haul from either place would be expensive.

Estimate of Cost.

Stripping damsite, 8,000 cubic yards at 25 cents	$2,000	
Cut-off trench—		
Excavation, wet, 6,000 cubic yards at $3	18,000	
Excavation, dry, 2,000 cubic yards at $1	2,000	
Clay puddle, 8,000 cubic yards at $1	8,000	
Earth embankment, 175,000 cubic yards at 50 cents	87,500	
Riprap, 6,000 cubic yards at $3	18,000	
Concrete lined outlet conduit, 375 lineal feet at $20	7,500	
Gate tower and gates	7,500	
Wasteway—		
Excavation, 10,000 cubic yards at 75 cents	7,500	
Masonry, 1,000 cubic yards at $10	10,000	
New roads, etc.	4,000	
Total cost of construction	$172,000	
Engineering and contingencies at 25 per cent	43,000	
Total		$215,000
Lands and damages—		
2,860 acres submerged.		
4,000 acres purchased.		
2,000 acres grain and meadow land and improvements at $40	$80,000	
2,000 acres pasture and hill land at $15	30,000	
Miscellaneous damages	10,000	
Total lands and damages		120,000
Total cost construction, lands and damages		$335,000

On the basis of 47,000 acre feet annual net supply the cost of storage would be $7.13 per acre foot.

BIG VALLEY RESERVOIR.

In the report on the Iron Canyon project previously referred to Big Valley reservoir site has been shown to be unsuitable for large storage for use in the Sacramento Valley. It is likewise impracticable for use for the development of small storage, even should there be found lands along Pit River below this site on which a supply from it could be utilized. For instance, 6,000 acres would be submerged to impound 20,000 acre feet, whereas the same supply could be stored with far less loss in evaporation and at a much less cost by flooding only about 900 acres in Little Valley, just below Dixie Valley, on Horse Creek. Further discussion of this point is needless.

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MISCELLANEOUS STORAGE SITES.

Introductory. Many small storage sites were examined to determine possibilities for developing small supplies. Some of these sites, such as Delta Lake and those on Pit River above Lookout, and on Willow Creek, were strongly recommended by various persons and only for that reason are they commented on herein. It was evident at once that lack of drainage area rendered the Delta Lake site valueless, and the expense of constructing dams in Pit River between Big Valley and Warm Springs Valley for small storage made any development of that kind impracticable, as shown in detailed report following. Other sites are even less important.

Delta Lake. Six miles northwest of Likely, on the plateau at 5,500 feet elevation, are two small bodies of water, the larger of which is called Delta Lake. As the lake occupies a depressed basin it has been proposed to drive a tunnel some 1,500 feet in length through basaltic lava rock to secure a water supply from the lake for lands in South Fork Valley. A canal to carry this water some miles over the plateau to reach lands within five miles of Alturas has also been considered.

When Delta Lake was visited in October, 1914, the water surface covered about 100 acres. As 1913–14 was a year of fairly large run-off for the bench lands, it may be considered that about 150 acres represents at least the average lake area. The maximum area would be about 200 acres as indicated by high water marks. It appears very probable that at high water stages there may be considerable loss from seepage through the porous basaltic lava slopes at the north.

The drainage area consists of not over three square miles of almost barren hill lands 5,500 to 6,000 feet in elevation, on which precipitation probably does not exceed 14 to 15 inches. The precise yield of the watershed can not of course be determined but, except for such seepage losses as may occur, and which can not be recovered, the run-off is balanced by the evaporation on the pond, probably not more than three feet in depth over an average area of 150 acres, or about 450 acre feet annually. At least 150 acre feet would in any event be lost in evaporation before the remaining 300 acre feet could be collected and used for irrigation. To drive 1,500 feet of tunnel at an expense of at least $10 per foot, or $15,000 total, to secure 300 acre feet at a cost of $50 per acre foot for storage alone does not need discussion.

It has also been proposed to divert some of the drainage tributary to Crooks Canyon into this basin. Apparently there is an opportunity to store water directly in a reservoir in Crooks Canyon in a basin fully as impervious as that of Delta Lake, hence it would be entirely impractical to make expensive diversions to carry water from Crooks Canyon into Delta Lake and thereafter drive a tunnel into the lake to obtain

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the stored supplies. This lake is not of any practical value for the development of a water supply of material amount.

Crooks Canyon. Crooks Canyon is about 6 miles northwest of Likely. The drainage tributary to this canyon is about 45 square miles of plateau and mountain area ranging from 5,000 to 7,000 feet elevation. The damsite is about one-half mile northeast of Delta Lake.

The higher slopes of the drainage area are fairly well timbered while the bench lands are a rocky prairie. The annual precipitation over the area ranges from 14 to 18 inches. In ordinary years a run-off of about 8,000 acre feet might be furnished by this watershed, but in dry years probably not more than 2,000 acre feet.

Big Sage. The very flat adobe capped plateau area northwest of Alturas tributary to Rattlesnake Creek is known as Big Sage. The elevation of this area ranges from 5,000 to 5,500 feet. The sole vegetation over these bench lands consists of sagebrush and patches of scattering juniper. Only a very small portion of the area has agricultural value on account of the large quantity of loose rock which covers a large proportion of the surface.

Over this drainage area of about 110 square miles the average precipitation is probably about 15 inches. In summer all rainfall, except when very heavy thunder storms or cloudbursts occur, is absorbed by the adobe and evaporated. Even in winter most of the precipitation is absorbed and retained until evaporated. Unless climatic conditions are such as to cause a rapid melting of the snow in spring a very small run-off results. The extreme unreliability of run-off from this type of drainage area even in normal years, and the certainty of failure in dry years, which seem to occur about every fifth year, appear to place a dependable development at this place out of the question.

The only available reservoir site is likewise unfavorable, the surface area being very large so that serious losses by evaporation and seepage may be expected. The wide shallow outlet from the basin would moreover require a dam about 500 feet in length and 30 to 50 feet high.

It is quite certain that a storage project here would not prove dependable for more than 5,000 to 10,000 acre feet during four years out of five, and that complete failure in supply might be expected about every fifth year. With several dry years in succession, as have occurred twice in the past twenty years, the failure of water supply would result in great loss to lands depending on it. In the light of our present knowledge it is not believed that this supply would warrant the expense of its development.

Sites on Pit River Between Warm Springs and Big Valley. The section of Pit River between Warm Springs Valley and Big Valley lies generally in a narrow, rocky gorge, along which there are no flat

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valleys at river level. Stone Coal Valley lies 50 feet or more above the river and the valley below Stone Coal has a fairly steep grade and does not offer a favorable opportunity to develop storage. At both of these valleys dams of excessive height and expense would be required. No other points offer prospect of economical storage. Plans to build a number of low dams about 30 feet high in the ordinary river channel below such small open sections of the river as may be found have been discussed, and appear attractive as regards low value of lands destroyed, but the total expense of such dams would render the cost of such storage utterly out of the question.

Widow Valley. Widow Valley is about six miles southwest of Lookout, at the base of the highest peak of Big Valley Mountain. The 17 square miles of drainage area is heavily timbered, indicating an average precipitation of about 24 inches. The valley consists of a very narrow strip of meadow land about 600 acres in area. One-half mile above the lower end of the valley a low earthen dam or levee averaging 25 feet in height and 1,200 feet long might be constructed and a storage of 3,000 to 5,000 acre feet secured. While this project has the disadvantage of flooding 500 acres, an area relatively large for the storage secured, it is deserving of some consideration on account of the fact that it is well located near high irrigable areas at the west side of Big Valley, to which it would be difficult to deliver water from any other source.

Willow Creek. Willow Creek flows from the hills at the southeast of Big Valley and joins Ash Creek about 7 miles west of Adin. Before reaching the valley the creek has a steep grade and no open flat areas are found along its course. Two of the possible reservoir sites that had been urged for consideration by some local residents as most favorable were visited. Dams 75 to 100 feet high, costing possibly from $200,000 to $300,000, would enable the flooding of about 100 to 200 acres of land to an average depth of 30 to 50 feet. This would only furnish in each instance storage considerably less than 1,000 acre feet, which would cost as much as $300 per acre foot or $600 per acre irrigated. These approximate costs are submitted to indicate the impracticability of storage at such sites.

Ash Creek Valley. Storage in Ash Creek Valley, an extremely flat basin 12 miles southeast of Adin, with a damsite on Ash Creek below its junction with Cottonwood Creek, might be developed. Nearly two-thirds of the water supply tributary to Ash Creek at Adin is furnished by the drainage area tributary to the Ash Creek Valley site. Probably about 30,000 acre feet of unappropriated supply might be obtained annually by storage at this place.

As the cost of storage works and lands damaged would amount to nearly as large a total cost as at Round Valley, where a net storage

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yield of about 47,000 acre feet may be secured, the cost per acre foot of storage at this site would probably be fully 50 per cent greater than at Round Valley. There would, therefore, be a decided disadvantage in cost for storage at Ash Creek Valley, as compared with Round Valley and hence this site has not been further considered.

Dixie Valley. This valley is at the head of Horse Creek about 16 miles south of Bieber. It consists of 1,200 acres of meadow and some 3,000 acres of border land that has possible agricultural value. The valley receives drainage from about 175 square miles of watershed ranging from 5,000 to 6,000 feet in elevation. The well timbered mountain area at the south of the valley receives about 24 inches of precipitation, while the lower portions of the basin probably receive 18 inches. In the absence of definite data as to stream flow it may be assumed that fully 25,000 acre feet of storage might be impounded in this valley.

The damsite at the outlet of Dixie Valley is less than 100 feet in width. The formation is basaltic lava rock, and on account of the very flat slope of the valley a dam of less than 50 feet in height probably would be sufficient to impound the entire run-off. This appears to be a very favorable storage proposition, but unfortunately there are very few irrigable lands below it in need of an additional supply, hence it may be considered infeasible.

Little Valley. This valley is on Horse Creek about one mile below Dixie Valley. On the topographic maps of the U. S. Geological Survey it is shown as Ash Creek Valley. The drainage tributary to this valley is about 198 square miles. The valley floor is about 900 acres in area. An apparently favorable damsite about 100 feet in width is found at the valley outlet. On account of the very flat grade of this valley a dam 70 to 100 feet in height would probably be sufficient to impound the average run-off, amounting to approximately 30,000 acre feet. Due to lack of tributary irrigable lands, this storage site may be classed as infeasible.

Great Spring on Hat Creek. At Great Spring on upper Hat Creek, about 20 miles above Cassel, there is a fair reservoir site. The damsite is immediately below Great Spring, where the creek passes between high basaltic walls about 250 feet apart. The site seems well adapted for a rock-fill earthen dam, although it is uncertain how deep bedrock would be found below the creek bed. The valley above rises quite rapidly, and it probably would be necessary to build a dam fully 75 to 100 feet high to secure a storage capacity of 50,000 to 75,000 acre feet. It does not appear that storage at this place is liable to be required for any purpose.

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SUMMARY OF STORAGE POSSIBILITIES.

Of the reservoir sites considered Jess Valley and Round Valley are the only ones that stand out conspicuously as favorable for development on a considerable scale. The cost of development is comparatively low, the areas submerged in the basins are small and the valleys are well located to irrigate tributary lands.

At Warm Springs Valley the cost of storage is high and the areas flooded are large. The smaller sites considered are generally impracticable for various reasons mentioned in the detail discussion or are of such small yield that they can be considered only for the irrigation of very minor areas.

The sites at Dixie and Little Valleys are favorable from the water supply and construction standpoints, but due to lack of irrigable lands below them there appears no necessity for development. Likewise the site on Hat Creek at Great Spring, although favorable, is of little present utility for irrigation.

AREAS IRRIGABLE BY NATURAL OR UNREGULATED STREAM FLOW.

FALL RIVER VALLEY.

The complete reclamation of an additional 10,000 acres of swamp land in Fall River Valley will probably continue along the lines of levee construction and drainage described in the section on "Principal Irrigation Works" under "Fall River Valley" in the chapter on "Present Appropriations and Uses of Water." An abundant irrigation supply is available from Fall River and its tributaries.

The extension of irrigation in Fall River Valley by pumping with lifts of from 10 to 25 feet involves no problems of water supply. With the completion of the power plant of several hundred horsepower at Fall River Mills and the extension of transmission lines to the various parts of the valley, all of which were under construction in 1914, electric power as well as that produced by steam or gasoline or other oils will be available for pumping.

In addition to supplies from Fall River and from springs feeding Fall River, artesian conditions are indicated by several wells drilled to a depth of about 400 feet at the north of McArthur and Pitville. The yields are from 0.1 to 0.3 second feet. The formations encountered are largely sands and clays, with gravel or rock at the bottom. One of these wells is two miles north of McArthur on the McArthur ranch, the other being three miles northeast of McArthur on the ranch of Dennis

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Sesnoy. Other wells with small artesian flow have been obtained by drilling along the south border of Fall River Valley in the vicinity of Pitville.

HAT CREEK VALLEY.

Along Hat Creek from Great Spring to Carbon about 4,500 acres of irrigable land remain unirrigated. When these lands are cleared of timber, diversions can easily be made from Hat Creek, which has a steep grade and an ample supply.

BENCH LANDS SOUTHWEST OF CASSEL.

On the bench about three miles southwest of Cassel, largely on the north side of the road from Hat Creek west to Burney, there is an area of about 5,000 acres of timber land, of which about 4,000 acres, when cleared, may prove suitable for irrigation development.

A canal heading from Hat Creek about five miles upstream from the above described area should have sufficient grade to deliver water to the south or higher side. Should the supply of Hat Creek be deficient, water from Loss Creek can be carried to Hat Creek by a canal about two miles in length. The main canal from Hat Creek probably would cost $10 per acre irrigated and should it be necessary to carry a supplementary supply from Loss Creek to Hat Creek, the cost would probably be increased to $15 per acre. The expense of distributing laterals is assumed at $7.50 per acre, making the total cost $17.50 to $22.50 per acre for main canal and distribution.

BENCH LANDS WEST OF CASSEL AND LANDS IN BURNEY VALLEY.

On the bench west of Cassel, and in Burney Valley there is a total gross area of 15,000 acres, of which about 10,000 acres appear suitable for or warrant irrigation development. These lands are now timbered, about three-fourths of the entire area being in private ownership. An examination of the public lands by the United States Forest Service indicated that soil conditions were satisfactory for irrigation development, but that temporarily the lands were chiefly of value for timber. Hat Creek is the only source of supply for the irrigation of these lands, as Burney Creek water is entirely appropriated.

The main canal for the irrigation of the greater part of this area would head about one-half mile above Cassel, following generally for the first three miles the location of the Braden ditch, which was started as a large canal to irrigate much of the area under consideration. About four and one-half miles west of Cassel it would be necessary to build the canal around the north end of a high lava dike. The total net irrigable area below or north of this main canal probably amounts to about 7,500 acres. A large portion of the canal would be located on

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the side hill in rather difficult excavation. The total length would be about 12 miles. Including structures it would cost about $15.00 per acre irrigated.

The distribution system would require one or two important laterals to the northwest to reach bench areas isolated by lava dikes. The cost of this system is approximated at $10 per acre, making the total cost of irrigation works about $25 per acre.

To reach lands in Burney Valley which are south of the above-described main canal, it would be necessary to extend the canal previously described as heading some seven miles about Cassel for the irrigation of the 5,000 acre tract three miles southwest of Cassel. While it appears that this canal can be extended to the west so as to cross the lava flow east of Burney, no surveys have been made to determine how expensive such a project might be, but indications are that the cost would be high. The net area east of the lava dike that may be irrigated by this canal would probably not exceed 2,500 acres.

SUMMARY OF PROPOSED DIVERSIONS FROM HAT CREEK.

The amount of water diverted for irrigation in Hat Creek Valley probably totals two and one-half feet depth in a season. After making allowance for return flows, it is estimated that the net use of water for the 21,000 acres of irrigable lands which can be supplied from Hat Creek will not exceed about 200 second feet for four to five months of the year.

MISCELLANEOUS AREAS.

In the estimates herein given of areas possible of irrigation in the Pit Basin account has been taken of a number of small projects where in individual cases areas ranging from a few hundred up to possibly 1,000 or more acres can be developed by means of small storage or by new canals. No attempt is made herein, however, to specify such small projects in detail.

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AREAS IRRIGABLE UNDER STORAGE RESERVOIRS.

UNDER JESS VALLEY RESERVOIR.

Location and Description. In South Fork and Warm Springs valleys, and in the immediate vicinity of Alturas, there is a total irrigable area of about 46,000 acres, of which about 40,000 acres is suitably located and adapted for irrigation from storage at Jess Valley. About one-half of this area is now supplied with water from the natural stream flow, supplemented with a small amount of storage; the other half is entirely without a supply.

The irrigated lands consist mostly of the valley bottoms which lie close to the level of the stream courses. These lands have an abundant water supply in May and early June, but their supply is generally deficient by the middle of June. As previously stated, the amount of water used on these lands averages about two feet in depth in a season, or a total of 40,000 acre feet for the entire area.

The irrigable lands which have no water supply are scattered the entire length of South Fork and Warm Springs valleys, and consist generally of smaller areas at high level along the edge of the valleys. In South Fork Valley the largest area is on the west side within ten miles of Alturas. In Warm Springs Valley lands of this character are found mostly in the lower or west half of the valley.

Present conditions may be summarized as follows:

Locality	Lands suitable for development under Jess Valley storage		
	Irrigable acres	Irrigated acres	Dry acres
South Fork Valley, including lands adjacent to Alturas	25,000	18,000	7,000
Warm Springs Valley	15,000	2,000	13,000
Totals	40,000	20,000	20,000

Two alternative plans of development may be followed in utilizing the storage from Jess Valley. First: Jess Valley storage of 40,000 acre feet may be used exclusively for 20,000 acres of irrigable lands mostly in Warm Springs Valley, now without a water supply; second: Jess Valley storage may be used to so supplement the natural stream flow for the 20,000 acres now irrigated as to furnish a well regulated supply for the full season instead of the unregulated supply that now obtains, with its deficiency in the summer. This will permit of such economies in

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use as to enable the additional 20,000 acres of irrigable land now without any supply to be watered as well.

Referring to the first alternative plan, the 20,000 acres not now irrigated comprise a large number of scattered areas located largely at the lower half of both South Fork and Warm Springs valleys and adjacent to Alturas. To supply them it would be necessary to construct four main canals. The two for South Fork Valley and Alturas areas would head about three miles east of Likely, the two for Warm Springs Valley near Alturas. The aggregate length of these canals would be about 150 miles. As they would be located to a considerable extent along the side hill, and areas to be supplied are largely near their ends, the canals would be relatively large and expensive. It is probable that the main canals would cost $20 to $25 per acre irrigated. Storage would add $10.40 per acre. The distributing laterals would cost about $7 per acre. The total cost of the works would therefore be about $40 per acre. Such a development is not only unduly expensive, but it would not serve the best interests of the valleys concerned, as it would tend to result in the intensive cultivation of the border lands, which probably as a whole are of less agricultural value than the bottom lands that would remain with a deficient summer water supply.

Referring to the second alternative plan, the expense of storage would be spread over 40,000 acres, the apportionment being presumably prorated according to the priority of water right and the benefit received. The cost per acre for main canals would be much lower under this plan, which would introduce a common system of water supply and distribution and prevent disagreement as to the ownership of water, and is to be greatly preferred over the plan first mentioned. The following description of proposed works refers only to this plan.

No attempt is made herein to outline definitely any district which storage at Jess Valley might serve. So far as possible the flows of Pine Creek, North Fork and Canyon Creek, and storage now developed, or any which may later be developed, on the plateau southwest and northwest of Alturas, should be used on lands that can not be reached by storage from Jess Valley. All advantageous readjustments of water supplies which would serve to bring the greatest area possible under irrigation would readily suggest themselves at the time, should Jess Valley storage be developed.

Main Canals, South Fork Valley. A canal heading about 3 miles east of Likely and extending along the base of the plateau, following possibly for much of the distance the present location of the Williams or Corporation ditch, would be carried north at sufficient elevation to cover lands on Pine Creek and possibly some areas at the east and at the north of Alturas. This canal would be approximately 35 miles in length. Much of the excavation would be in cemented material. One

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or two flumes or pressure pipes would be required to cross such low places as the Fitzhugh Creek bottoms. Except across Pine Creek lands, the cost of rights of way should be nominal. It is estimated that 10,000 acres would be supplied by this canal. The present east side Corporation ditch heading below Likely might serve a considerable portion of this area to advantage, and thus reduce the size and cost of the proposed main canal above referred to.

The delivery of water to all lands on the west side of South Fork Valley is not so simple. It is probable that these lands could be irrigated most economically by two canals, one heading about 3 miles east of Likely and following for some distance the present high line canal, known as Dukes Ditch, and one heading near Likely. The first canal would extend along the south side of South Fork Valley to a point northwest of Likely. This canal would be about 8 miles in length and would irrigate about 3,000 acres. The second canal, heading near Likely, would extend northwest to the west side of South Fork Valley and continue practically to Pit River, a distance of 30 miles. While the location would be on the side hill for much of the distance, the canal would have the advantage of delivering a large part of its supply to lands near its head, thus permitting of a rapid reduction in section. The cost of right of way would be very low. An area of 12,000 acres would be irrigated under this canal.

Supply for Warm Springs Valley. The water supply for lands in Warm Springs Valley would be carried down the South Fork of Pit River, probably in an enlarged channel excavated to improve drainage conditions in South Fork Valley. It would be necessary to make diversions for a north side and a south side canal a short distance below Alturas in order to deliver water to lands in Warm Springs Valley fairly well above the level of the valley bottom, as the lower portion of Warm Springs Valley, like the lower end of South Fork Valley, is of extremely flat grade. The canals through this valley would encounter considerable side-hill excavation in cemented materials. Each canal would be about 35 to 40 miles in length. The north side canal would irrigate about 9,000 acres, and the south side canal about 4,000 acres. Rights of way would generally be low in cost.

Estimate of Cost of Canals. The average grade available for all canals would be about two and one-half feet per mile. To this estimate an overhead charge of 25 per cent. has been added for engineering and

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contingencies. No surveys have been made as a basis for these estimates. The following is a summary of cost for the main canals:

	Area Irrigated, acres	Length, Miles	Total cost
South Fork Valley—			
East Side Canal	10,000	35	$130,000 00
Upper West Side Canal	3,000	10	18,000 00
Lower West Side Canal	12,000	30	150,000 00
Warm Springs Valley—			
North Side Canal	9,000	40	160,000 00
South Side Canal	4,000	35	75,000 00
Totals	40,000	145	$533,000 00

Cost per acre irrigated	$13 50
Allow for structures	1 50
Total	$15 00

Distribution System. In this system the length of main canals in proportion to the area irrigated is so great and the average width of lands adjacent to these canals so small, that while the main canal charges will be high the expense of laterals should be comparatively low. The latter are estimated at $7.50 per acre.

Summary of Costs. The total expense of the works outlined should be about as follows:

	Total cost	Cost per acre
Storage, 40,000 acre feet	$208,000 00	$5 20
Main canals, 155 miles	600,000 00	15 00
Distribution system, 40,000 acres	300,000 00	7 50
Total cost	$1,108,000 00	$27 70

or, say, an average price of $28.00. No attempt is made to apportion the charge for new and for old lands. It is presumed that charges for the 20,000 acres now irrigated would be substantially lower than for lands without any water rights.

Drainage. While drainage is not properly a charge against irrigation, a considerable portion of the area outlined requires additional drainage before any change from present irrigation and crop conditions can be considered. In South Fork Valley the ground water level is very close to the surface; for much of the valley, practically at the surface. With so high a ground water plane practically no crop but wild hay is possible. To secure a more economical use of water and permit of a higher grade of crops, the water level should be lowered as

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much as 6 or 8 feet in portions of the valley bottom. This can be accomplished by means of deep drains, the type and location of which need not be now specified.

In Warm Springs Valley the flow of the Pit frequently exceeds 5,000 second feet. The maximum recorded flow in 1904 was 17,000 second feet. The river has practically no channel capacity and the grade is extremely light, especially in the lower or west half of the valley. It will therefore be very expensive, if not prohibitive in cost, to prevent occasional flooding of some of the lower lands for a few days in spring.

UNDER ROUND VALLEY RESERVOIR.

Location and Description. Big Valley has a total agricultural area of 83,000 acres. (See Report of 1912, State Conservation Commission.) The maximum gross area under the highest practicable gravity canals heading from Round Valley Reservoir and extending around Big Valley is about 42,000 acres, excluding about 3,000 acres of lands too high for gravity irrigation. Excluding lands unsuitable for irrigation it is estimated that the net irrigable area is about 30,000 acres. Of this area 15,000 acres is now partly irrigated, the water supply being generally deficient. The remaining 15,000 acres is not irrigated nor is a water supply available without storage development.

The irrigated lands consist mainly of meadow and reclaimed swamp lands along Ash Creek, of meadow lands along Willow Creek, of hay and alfalfa lands along Pit River, a small meadow area along Bull Run Slough, and alfalfa lands under the C. W. Clark Company ditch, east and south of Bieber. This area of 15,000 acres has an average water supply of about 17,000 acre feet, consisting of about 10,000 acre feet from Ash Creek, about 5,000 acre feet from Pit River and about 2,000 acre feet from other sources, chief of which is Willow Creek.

It is suggested that an advantageous utilization of water supply would be to divert all supplies that are of sufficient elevation to irrigable lands along Willow Creek and Pit River above Lookout which are too high to be reached by canals from Round Valley. This amounts to fully 4,000 acre feet and would leave about 13,000 acre feet of natural stream flow, mainly in Ash Creek, for the use of irrigable lands in the district outlined.

A considerable portion of the irrigable lands now without a supply are between Adin and Lookout on the north side of Ash Creek, and the remaining areas are more or less scattered throughout the valley.

Probably the most advantageous use of Round Valley storage would be both as a supplementary supply for the 15,000 acres of land now enjoying only partial irrigation, and for the full irrigation of the 15,000 acres of irrigable land now without any supply. The supply

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as developed by storage will be adequate for the 30,000 acres on the basis of 2 acre feet per acre irrigated, as shown below:

Natural stream flow	13,000 acre feet.
Round Valley storage	47,000 acre feet.
Total	60,000 acre feet.

Should it be found that all the storage at Round Valley can not be used advantageously in Big Valley, any surplus might be applied to lands below Big Valley.

North Side Main Canal. For the first six miles this canal would be at an average distance of one-fourth to one-half mile south of the road between Adin and Lookout. In the four miles east of Lookout it would be one-half mile to one mile or more north of the road. The general course below Lookout would be south, with necessary detours to the west around low areas. This canal, approximately 45 miles in length, would irrigate about 15,000 acres.

South Side Main Canal. In the first five miles the South Side Canal location is within about one-half mile of Ash Creek. It then extends in a general southwesterly direction and at an average distance of one-half mile southeast of the C. W. Clark Company canal to a point about three miles east of Bieber, whence it would extend in a southerly direction to the lower end of Big Valley. The total length of the canal would be 30 miles. About 15,000 acres could be irrigated under this canal.

Cost of Canals. The location of the canals would generally be through rolling lands, ranging in formation from earth to cemented materials. The grade would vary from two and one-half to three feet per mile. No unusual structures, except possibly a flume crossing Willow Creek, would be required. Rights of way should be uniformly low in cost.

	Area Irrigated, acres	Length, Miles	Total cost
North Side Canal	15,000	45	$160,000 00
South Side Canal	15,000	30	140,000 00
Total	30,000	75	$300,000 00

Average cost per acre	$10 00
Add for structures	1 50
Total	$11 50

An allowance of 25 per cent overhead expense for engineering and contingencies is included in the above estimate.

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Distribution System. The irrigable lands are all within from one to three miles of the main canals. The estimated cost of the lateral system is assumed not to exceed $7.50 per acre.

Summary of Costs. The total construction cost of the project as outlined is therefore as follows:

	Total cost	Cost per acre
Storage, 47,000 acre feet	$335,000 00	$11 17
Main canals, 75 miles	345,000 00	11 50
Distributing laterals, 30,000 acres	225,000 00	7 50
Total cost	$910,000 00	$30 17

Say in round numbers $30.00 per acre.

Similarly as in the case of lands under the Jess Valley storage, any equitable plan of apportionment of construction charges to the lands should take into account rights already vested and works already constructed and capable of utilization, and apportion charges accordingly.

Drainage. Drainage conditions in Big Valley appear to be generally fairly satisfactory except where affected by dams and obstructions placed in the river channels. Some lands, mainly west of Bieber, are flooded in spring by overflow from the Pit. These floods are of short duration, generally lasting not more than three days. No item for drainage is allowed for in estimates of cost of reclaiming these lands.

POWER DEVELOPMENT POSSIBILITIES.

GENERAL.

Consideration in this report to water power possibilities on the streams in the Pit River basin is given mainly to show the extent, if any, of interference between possible development of power, irrigation, flood control or storage works. On this account no account is taken of power development possibilities on the McCloud or other tributaries on which irrigation or storage works are infeasible. Power can be developed in large quantities along the main stream of the Pit below Fall River Mills and on tributaries entering below that point; the various irrigation and storage works above that point, discussed herein, interfere with these power possibilities to some degree, and this chapter discusses these in detail.

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POSSIBLE POWER ABOVE FALL RIVER.

Above the junction with Fall River the Pit is usually dry during the summer months, all supplies from tributary streams being used for irrigation. All storage that can be obtained at reasonable cost will also be needed to irrigate local lands. As a result, hydro-electric development will probably be confined to small perennial streams on which no favorable storage sites exist, and at no time will the development of power in this region be of large amount. A small installation of about 300 horsepower on Pine Creek now supplies the market at Alturas and Cedarville. Doubtless other small developments are possible especially on the streams issuing from the Warner range, but none of these are affected by nor do they affect irrigation possibilities in this basin.

POSSIBLE POWER FROM FALL RIVER TO MOUTH OF THE PIT.

Fall River. From February, 1912, to September, 1913, a total of 20 months, the mean flow of Fall River was 1,410 cubic feet per second, the minimum about 1,250 and the maximum about 1,600. As this period was one of low run-off in northeastern California, being only 64 per cent for the Sacramento River basin above Red Bluff, a longer record on Fall River would probably give a slightly higher value for the mean flow. With complete reclamation of swamps and irrigation of all suitable lands, the flow of Fall River may be reduced about 150 second feet during four to five months of the year.

Hat Creek. Hat Creek is supplied from three main sources, Upper Hat Creek, Rising River and Crystal Lake, all of which issue from springs. Upper Hat Creek was measured from August, 1911, to August, 1913, at the Hawkins Ranch near the head of Hat Creek Valley. The total creek flow, together with irrigation diversions, averaged about 190 cubic feet per second with a minimum of about 130 and a maximum of about 220. It is probable that a longer record would show a slightly larger mean. Irrigation of all lands adjacent to Hat Creek will require the entire flow of this portion of the creek during four to five months of the year.

Rising River probably obtains some of its supply from the waters of Loss Creek, a stream of over 75 second feet in discharge which sinks after flowing one and one half miles. Loss Creek is probably supplied in large part from Butte Creek, another stream which sinks after flowing a few miles. Rising River from August, 1911, to September, 1913, had a mean flow of about 375 cubic feet per second, with a minimum of 290 and a maximum of 490. A longer record would probably furnish a slightly greater value for the mean discharge.

Crystal Lake is supplied entirely from spring flow. Its discharge into Hat Creek is very uniform and amounts to approximately 150

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PIT RIVER AT JUNCTION OF FALL RIVER LOOKING UP-STREAM TOWARD THE FALL RIVER RESERVOIR.

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FALLS ON PIT RIVER THREE MILES BELOW FALL RIVER MILLS.

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second feet. Small springs entering between Cassel and Carbon add about 50 second feet to the flow of Hat Creek.

The total flow of Hat Creek below Crystal Lake is therefore about 750 cubic feet per second, including irrigation diversions, which under the present lavish methods of use on the stream amount to over 100 second feet. With complete irrigation of all lands in Hat Creek Valley, and such others at the west as may be supplied from this stream, 200 second feet during four or five months of the year will probably be required, thereby reducing the flow of Hat Creek at Cassel, two miles below Rising River, from about 550 to 350 cubic feet per second, and of lower Hat Creek near Carbon from 750 to 550 cubic feet per second. Stream flow might be regulated by storage at Great Spring.

Burney Creek. Records of discharge have been made on upper Burney Creek for several years. The summer flow is entirely used for irrigation. At the lower end of Burney Valley the ground water storage, obtained from upper Burney Creek and other tributary areas, issues in fairly well-regulated spring flow and discharges over Burney Falls with a drop of 110 feet. Miscellaneous measurements by the United States Geological Survey of the flow of Burney Creek, some distance below the falls, show as follows:

Sept. 15, 1902	209	cubic feet per second.
Sept. 9, 1903	210	cubic feet per second.
Sept. 25, 1910	246	cubic feet per second.
Sept. 5, 1912	146	cubic feet per second.

McCloud River. Measurements of discharge on McCloud River have been made for over ten years. The mean flow is very nearly 2,200 cubic feet per second, with a minimum of 1,150 and a maximum of 41,500. The supply is largely from springs, but at times a considerable surface run-off occurs. There are practically no irrigable lands in the basin of this river. No large storage sites are found along the McCloud, the river being in a deep and narrow canyon.

Smaller Tributaries. Kosk and Squaw creeks enter the Pit from the north, while Hatchet and Montgomery creeks enter from the south. None of these streams have a large low water discharge. Kosk and Squaw creeks fall below 30 cubic feet per second in summer, while Hatchet and Montgomery creeks drop to less than 20 cubic feet per second.

Pit River, Below Fall River Mills. On Pit River, below the junction with Fall River, there are two gaging stations, one at Henderson above Kosk Creek, on the big bend of the Pit, and the other at Silverthorne Ferry near Ydalpom post office, one half mile below the mouth of Squaw Creek, about four miles above the mouth of McCloud River, and seven miles above the junction with the Sacramento. The entire channel of the Pit from Fall River to the Sacramento is in a deep, narrow, rocky gorge.

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At Henderson the mean flow from January, 1912, to August, 1914, was about 3,600 cubic feet per second, with a minimum of about 2,500 cubic feet per second and a maximum of about 12,000 cubic feet per second. This period was about normal in run-off. The normal low water flow is usually considered about 2,600 second feet. This will be reduced to about 2,250 second feet during four to five months of the year if full irrigation development as herein outlined be accomplished.

At the lower station near Ydalpom the mean flow from November, 1910, to September, 1914, was approximately 5,400 second feet, with a minimum of about 2,740 second feet and a maximum of over 30,000 second feet. The period was below average in run-off. It is probable that the low water flow would be reduced to about 2,400 second feet during four to five months of the year on account of irrigation diversions as above outlined.

The total extreme low water flow of the Pit below the mouth of the McCloud is about 4,000 cubic feet per second, while that on the Sacramento at Red Bluff is about 4,200 second feet. Both of these flows will similarly be reduced about 350 second feet by irrigation development.

POWER PROJECTS ON HAT CREEK, FALL RIVER AND PIT RIVER.

Projected Projects. These are described in the following paragraphs which have been contributed by Mr. F. G. Baum, consulting engineer, of San Francisco.

Hat Creek, Between Cassel and Carbon. Near Cassel, rapids and falls totaling about 210 feet in about one mile have a normal flow of about 550 second feet, as stated in the preceding section on "Hat Creek" in this chapter. It has been estimated that this flow may eventually be reduced to a minimum of 350 second feet during several months of the year by irrigation diversions above; 6,000 to 8,000 horsepower may be developed.

Near Carbon a second series of rapids and falls occurs with a total drop of about 200 feet in a distance of about one mile. With a normal flow of 750 second feet, as stated in the section on "Hat Creek" previously referred to, reduced to a possible minimum of 550 second feet by irrigation diversions above during several months of the year, 9,000 to 12,000 horsepower may be developed.

No storage (except forebay storage) would be required and the flow conduit may be an open flume or wood stave pipe. The developments would be simple and it has been estimated that the cost of development would be about $60 per horsepower without transmission system.

Fall River, Near Fall City. Fall River has an average flow of about 1,410 second feet, as previously stated in this chapter in the section

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on "Fall River," with a probability of reduction by irrigation diversions above to 1,260 second feet. At Fall City there are falls and rapids totaling about 70 feet, so that about 7,000 horsepower may be developed.

It has been proposed to drive a tunnel from a point on Fall River a few miles up stream from Fall City, in a southwesterly direction, and drop the water of Fall River through a power plant located on the Pit River a few miles down stream from Fall City. A head or drop of about 400 feet can be obtained, giving about 40,000 horsepower. No estimates are available but the unit cost should be low. No storage is required. The pressure conduit would be about one mile long (in addition to two mile tunnel).

Big Bend of Pit River. It has been proposed to drive a tunnel across what is known as the Big Bend of the Pit River near Montgomery Creek. The flow of water available is about 2,600 second feet, as shown previously in this chapter in the section entitled "Pit River, below Fall River Mills." It is estimated that irrigation diversions will reduce this flow to 2,250 second feet during four to five months of the year. The head obtainable is about 800 to 900 feet, depending on the way it is developed. There can be developed, therefore, about 150,000 horsepower. No storage is required. The flow tunnel will be about seven miles long and the pipe line will be about one mile long. The length of flow tunnel and the size of tunnel will necessarily make the initial cost high unless a very large amount of power is developed for the initial stage.

Markets For Pit River Power. The natural development of the Pit River power posssibilities will come through the establishment of some electro-chemical enterprises relatively near the source of power. The development of this power for the more distant market, the San Francisco Bay region, need hardly be considered for the reason that there is so much undeveloped water power one hundred miles nearer. These nearby powers it is desirable to develop for the additional reason that the storage water developed as a necessary part of the hydro-electric power will become available for irrigation on lands for which there is a demand and also improve the low flow of the lower stretches of the navigable rivers.

The Pit River power can be developed at a low enough cost to attract industries requiring large amounts of power at a low price, and fortunately developments are available to meet large or small demands at about the same unit cost. For this low priced power the cost of transmission must be reduced to the lowest possible amount. The writer has repeatedly urged the manufacturers of cyanamid, and other large power users, to investigate this territory, and it is hoped that they will seriously consider these powers in the near future.

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FLOOD CONTROL AND NAVIGABILITY.

INFLUENCE OF UPPER PIT RIVER ON SACRAMENTO RIVER FLOODS.

During the past eleven years, for which time fairly complete records of run-off are available, there have been four exceptional periods of flood water discharge on the Sacramento River at Red Bluff. The Iron Canyon report states: "The first of these occurred on February 16, 1904, with a discharge of 188,000 second feet. Pit River at Bieber had its high water stage at 8,560 second feet on the day after the Sacramento at Red Bluff was in flood, and probably contributed less than 1,000 second feet to the 188,000 of the Sacramento at Red Bluff on February 16th.

"On March 20, 1907, occurred one of the most serious recent floods in the Sacramento Valley. The corresponding flows of the Sacramento River at Red Bluff and Pit River at Bieber were as follows:

Date	Sacramento, second feet	Pit, second feet
March 16	23,600	2,770
March 17	39,100	17,400
March 18	118,000	25,000
March 19	164,000	27,500
March 20	192,000	25,000
March 21	132,000	20,800
March 22	92,900	13,800
March 23	120,000	8,810
March 24	80,800	6,110
March 25	64,000	4,160
March 26	57,100	4,000

"From March 18 to 21 the Sacramento at Red Bluff discharged 1,200,000 acre feet; the Pit at Bieber discharged 195,000 acre feet.

"From the above it is evident that the Pit at Bieber contributed at the most about 15 per cent of the peak flow of the Sacramento during this flood, and about 16 per cent of the entire river discharge during the critical three days.

"During the high water on the Sacramento at Red Bluff from February 2 to 4, 1909, with a maximum mean daily flow of 254,000 second feet, it is doubtful if the Pit furnished any appreciable amount of the flow. As there were no gage heights observed at Bieber, the amount of precipitation and weather reports at Alturas are the only guide to the conditions on the upper Pit. During the first half of January there were 3.45 inches of precipitation, while the second half of the month gave only 1.02 inches with nothing after January 27th."

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In the weather report from Alturas January 31, 1909, the following statements were made:

"The lowest temperature (in California) was 21° below zero at Alturas on the 10th.

"On the summit, between Alturas and Cedarville, there is at least four feet of hard snow, and on the higher parts of the Warner range there is much more. Probably there is more snow on the mountains than at any time last winter."

No unusual precipitation occurred in February, the total for the month being only 1.58 inches. From February 1st to 4th only .04 inches of precipitation fell. Temperatures during the month were extremely low. The following statement of the weather observer at Alturas gives a summary of conditions during February:

"On the pass over the Warner range to Surprise Valley there is five feet of hard snow, and still more on the higher parts of the mountains.

"This has been the coldest and cloudiest February in the memory of the oldest inhabitants."

This evidence is quite conclusive that little or no snow melted during February and that the flow of the Pit at Bieber must have been very small.

January, 1909, was a month of record precipitation at Alturas and a number of other localities in northern California. February was also a very wet month at most places in northern California. A record of the precipitation at various places is given to show the relatively small amount received at Alturas.

Precipitation of 1909 in Northeastern California.

	January (inches)	February (inches)	Total (inches)
Alturas	4.47	1.58	6.05
Delta	53.28	28.78	82.06
Dunsmuir	32.60	20.87	53.47
Shasta	35.96	15.17	51.13
Redding	24.28	12.70	36.98
Red Bluff	13.42	8.20	21.62

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The Iron Canyon report states: "During the floods of January and February, 1914, the corresponding flows at Red Bluff and Bieber were as follows:

Discharge in Second Feet.

Date	Sacramento at Red Bluff	Pit at Bieber
1913—December 30	25,400	475
December 31	139,000	1,060
1914—January 1	151,000	1,900
January 2	144,000	2,702
January 3	116,000	4,370
January 4	----------	9,560
January 5	----------	13,000
January 6	----------	9,560
January 7	----------	6,960
February 19	59,800	2,490
February 20	102,000	3,220
February 21	160,000	3,520
February 22	94,500	3,680
February 23	70,200	3,370

"During 1914 the Pit, therefore, contributed a maximum of two per cent to the peak floods of the Sacramento at Red Bluff."

On February 2, 1915, the Sacramento River was again in flood, the maximum discharge at Red Bluff reaching about 270,000 second feet. On this date the Pit at Ydalpom was likewise at high stage, reaching however only about 30,000 second feet. Probably less than 10 per cent of this 30,000 second feet was contributed by the portion of the Pit above Fall River Mills, making the contribution from the Upper Pit less than two per cent of the flow of the Sacramento at Red Bluff on that date. All but a negligible part of the flood flow of the Sacramento at Red Bluff in February, 1915, was therefore caused by storm conditions local to the foot-hills at the head of the Sacramento Valley.

From the above analysis it has been shown that for the last five years of flood discharge on the Sacramento River at Red Bluff, namely, 1904, 1907, 1909, 1914 and 1915, the upper Pit played an almost negligible part in three out of five years as shown by actual records of run-off; that it furnished an almost negligible amount in 1909 as shown by records of weather conditions and other evidence, and that it contributed about 15 per cent to the flood flow of 1907 as shown by measurements. It is therefore evident that from the upper Pit, above the points where great storage is alone available, large flood discharge does not originate and that control of floods in the Sacramento Valley, by a reservoir at Big Valley or Fall River Valley, is impracticable.

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INFLUENCE OF IRRIGATION DEVELOPMENT IN THE PIT RIVER BASIN ON THE LOW WATER FLOW OF THE SACRAMENTO RIVER.

As previously stated, the Pit usually has practically no discharge above Fall River during the summer and early fall months. Irrigation development for lands in and above Big Valley can not, therefore, have any influence in reducing the low water flow of the Sacramento River.

Irrigation diversions from Fall River and Hat Creek, previously described, will probably reduce the low water flow of Sacramento River at Red Bluff about 350 second feet, or about 8 per cent of the extreme low water flow.

GENERAL CONSIDERATIONS CONTRIBUTING TO AND RESULTING FROM THE DEVELOPMENT OF THE PIT RIVER BASIN.

TRANSPORTATION.

Heretofore the live stock and lumbering industries have been almost the exclusive business of the Pit River basin. As a consequence transportation has been developed only to a sufficient extent to meet the demands of these industries. The McCloud River Railroad has constructed a line from Sisson on the Shasta division of the Southern Pacific east to Bartle. In the area west and north of Bartle extensive lumbering operations are carried on. The wagon haul from Fall River Valley to Bartle is 25 miles, from Hat Creek and Burney 35 to 40 miles, and from Big Valley 50 to 60 miles. It is common to drive livestock even greater distances, but the wagon haul is such that ordinary farm products can not reach outside markets. A moderate amount of business has recently developed in cheese making, although there is much inconvenience caused by difficulties of transportation.

At the extreme east of the Pit territory the Nevada-California-Oregon Railroad extends through South Fork and North Fork valleys. This is a narrow-gauge road from Reno, Nevada, to Lakeview, Oregon. The easterly territory of the Pit is therefore supplied with rail transportation requiring a comparatively short wagon haul.

The most serious lack of transportation facilities is in Big Valley, which is approximately 50 miles from any railroad point. Moreover the wagon roads to shipping points are built over mountain grades, thus adding to the difficulties of long haul.

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A number of routes have been surveyed or projected through the central portion of the Pit River basin. One, called the Goose Lake and Southern, is an extension of the McCloud River Railroad through Fall River and Big Valleys up Pit River to Alturas. Other routes projected consist of main line roads from the Klamath Falls region through Fall River or Big Valley to connect with the Susanville branch of the Southern Pacific; a similar line from Oregon south to the Pit and along this river to Fall River Valley, thence southwest through lower Hat Creek Valley and Burney Valley to the Sacramento Valley. There is no doubt that additional transportation facilities would be of great benefit to the valleys of the Pit and would result in a strong stimulus to irrigation and other development. There would likewise be constructed better wagon roads between the various valleys connecting with the important highways of the State.

INFLUENCE OF IRRIGATION DEVELOPMENT.

It appears that the crop production along the Pit and its tributaries now equals and possibly even exceeds the entire demands of the live-stock industry. Already cheese factories have been installed, and a creamery is now being started at Alturas. As irrigation supplies are made available for new lands and the crop production on the older areas is improved, it may be expected that a considerable development along the lines of dairying will result. The shipment of these and other finished farm products seems to be along the line of logical development for this region, which is 100 miles or more further distant from large markets than most other points in California.

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CONCLUSIONS AND RECOMMENDATIONS.

GENERAL.

A number of specific conclusions both as to existing conditions and suitable policies for the more satisfactory development and utilization of the natural resources of this region have been reached by the engineers of the reclamation service having charge of this investigation and by the Engineering Department of the State of California, with which they are co-operating. These are as detailed below.

Recommendations as to action by the United States and the State of California in disposing of or reserving public lands and waters and the future measurement of streams flowing by important damsites are also made by the same parties. No attempt has been made herein to formulate specific recommendations as to the adoption of any project, such action being outside of the purpose of this investigation.

CONCLUSIONS.

1. That in the Pit River basin there are about 180,000 acres of potentially fertile, irrigable land, of which about 40 per cent is now fully or partially irrigated.

2. That of the areas now irrigated only an insignificant proportion is well developed agriculturally, due in large part to unregulated water supplies and to unsatisfactory drainage conditions.

3. That Jess Valley and Round Valley offer the most favorable sites for the development of storage for use on lands in the Pit basin. There is good reason to expect that the cost of irrigation development under these sites will be in keeping with the expense usually incurred for similar and successful enterprises.

4. That lands in Fall River Valley can be advantageously irrigated by pumping, the supply being practically inexhaustible.

5. That lands adjacent to and in the vicinity of Hat Creek, that are not yet irrigated, can be readily irrigated by direct diversion without storage. These lands are, however, now mostly timbered, and their development is not a matter for immediate consideration.

6. That there are a number of small irrigation developments possible in various localities but that none of these involve large engineering problems.

7. That Willow Creek, in the Klamath basin, may be a possible supplementary source of supply for lands in Big Valley but this can only be ascertained by extended observation of the yield of the creek and by careful surveys and estimates of cost.

8. That under conditions of today Goose Lake is an impracticable source of water supply for territory in or below the Pit River basin.

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9. That irrigation development in the Pit River basin will not seriously interfere with future power development in or below the basin.

10. That irrigation development in the Pit River basin will reduce the low water flow of the Sacramento River at Red Bluff only about 8 per cent and will not, therefore, seriously interfere with the navigability of the river.

11. That floods in the Sacramento Valley can not be controlled by storage in the Pit River basin.

RECOMMENDATIONS.

1. That unentered public lands in and adjacent to Jess Valley and Round Valley as listed below be withheld from entry for future storage use:*

Township 39 North, Range 14 East, Mount Diablo Meridian:
Sections 1, 2, 11, 12 and 13—all.
Section 10—E. ½.
Section 14—N. ½, SE. ¼.
Section 23—E. ½.
Section 24—N. ½, SW. ¼.
Township 39 North, Range 9 East, Mount Diablo Meridian:
Sections 3, 10, 11, 13, 15, 16 and 22—all.
Section 2—W. ½, SE. ¼.
Section 4—N. ½, SE. ¼.
Section 9—E. ½.
Section 12—W. ½.
Section 14—N. ½.
Section 21—E. ½.
Section 23—W. ½.
Section 27—N. ½.
Township 40 North, Range 9 East, Mount Diablo Meridian:
Section 33—S. ½.
Section 34—S. ½.

2. That all other public lands in the Pit River basin which may be now withheld from entry under the Reclamation Act be restored to entry.

3. That no future appropriations of water for power or other purposes in the Pit River basin that will tend to limit or retard irrigation development in the basin be allowed by the State of California.

4. That measurements of stream flow on South Fork of Pit River near Jess Valley damsite and on Ash Creek at Adin should be resumed by the United States and the State of California.

The above are concurred in.

(Signed) W. F. McCLURE,
State Engineer of California.
E. G. HOPSON,
Supervising Engineer U. S. Reclamation Service.

*NOTE.—Not more than about 100 acres of unentered public land recommended for withdrawal is agricultural, most of the areas being steep, rocky, pasture land.

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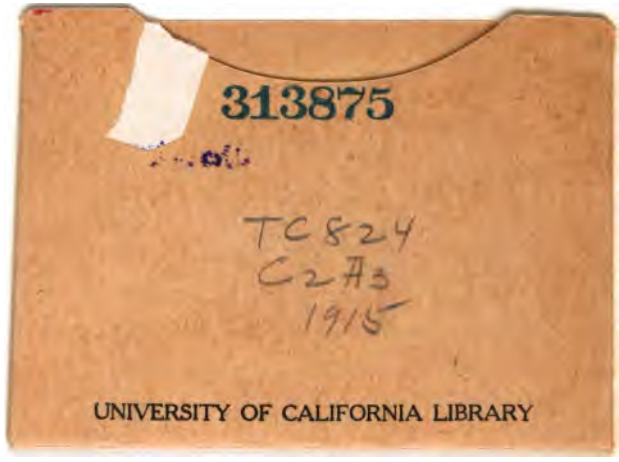

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